

TECHNICAL NOTE

Figure 6 shows the modelled 1d water levels for the EA baseline 1 in 100 AP event and PBA's 1 in 100 plus 25%, 1 in 100 plus 35% and 1 in 100 plus 70% for the new climate change flood levels.

The modelled flood levels are self-consistent (i.e. 1 in 100 plus 70% is greater than the plus 35% etc.)

The 2d modelled flood extents did not indicate any obvious errors.

The results for 267 nodes in the ISIS model were compared (largely ignoring spill units and structures). The average difference between the plus 20% scenario and the plus 25% scenario was approximately 55 mm with a standard deviation of approximately 15 mm (i.e. 2/3 of the differences were within +/- 15 mm of the mean). The difference for the 30% scenario compared to the 25% scenario was approximately 100 mm with a standard deviation of approximately 26 mm

For the plus 35% and plus 70% the average difference was approximately 350 mm with a standard deviation of 86 mm. There is a greater variation in the difference in water level between the plus 70% to plus 35% than the plus 25% to the plus 20% but in general the standard deviation in the mean difference in flood levels was around 1/4 of the mean difference.

Overall the results appear reasonable and there are no obvious indications of significant errors or oscillations in the modelled flood levels.

6 – EA model review

PBA submitted the proposed climate change modelling (+35% and +70% only as the 25% climate change modelling was not undertaken in time for submission for review) for the River Thames (Reading Complex Change model) for review by the EA in August 2016. The EA provided review notes in December 2016.

The comments in the review note were not significant and generally were regarding the suitability of the model cell sizes and the schematisation of buildings. These elements were unchanged from the base EA model and were considered appropriate as part of the original EA modelling.

As the modelling undertaken was to update to the existing EA models to the new climate change allowances, it was not considered appropriate to revisit the underlying assumptions in the model. The result of any amendments to cell sizes or building schematisation (either through changes to topographic levels (zpts) or Manning's n roughness) would alter the existing modelled results and have a knock-on effect to the EA Flood Zones which were based on the Reading complex change model. On this basis any changes to cell sizes or building schematisation would not be appropriate given the proposed uses of the updated climate modelling (the modelling undertaken by PBA is not intended to be appropriate for a Flood Zone review).

The EA comments for the model are appended to this note.

7 – Conclusion

The EA released new guidance on flood risk assessment climate change allowances in February 2016. This requires consideration of a range of allowances between +25% and +70% within the Thames River Basin to 2115.

The EA's Reading Complex Change hydraulic model has been run for the 1 in 100 AP plus 25%, 35% and 70% climate change scenarios.

The changes to the existing EA model were to scale the appropriate model inflows by 25%, 35% and 70%, and also to extend the Flow vs. Stage boundary at the downstream of the model for the 70% climate change scenario.

The modelled flood levels have been compared and are considered to be reasonably consistent, with no overarching problems in the model stability or flood levels. There may be local instabilities which would affect flood levels locally however these would need to be determined through local detailed

TECHNICAL NOTE

studies with local information. It is considered that the revised climate change modelling would still be appropriate at regional strategic level and would remain valuable for use at local levels if supplemented with local information and knowledge.

DOCUMENT ISSUE RECORD

Technical Note No	Rev	Date	Prepared	Checked	Reviewed (Discipline Lead)	Approved (Project Director)
1	-	25.05.16	SB	AH	RF	SM
1	A	30.01.17	SB – added 25% climate change runs and EA model review comments	AH	RF	MD

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ISIS/TUFLOW MODEL UPDATE Review

Study: Thames Climate Change update

Consultant: PBA

Model date: 04/07/2016

Modeller: Shumol Bari

This is an existing EA model and only the Climate Change approach has been changed (New February 2016 Policy applied).

Model Domain and DTM	
Check location and dimension of 2D grid. is the domain large enough/does it tie-in to high ground?	The New climate change policy requires an increase in inflows of 35% and 70% (instead of 20%). The significant inflow increase produces an increase in flood extent introducing the risk of glasswalling (as the code area was based on the 20% increase for climate change flood extent).
What is grid cell size? Is this suitable for the study?	10m cell size was used. Considered the purpose of using the model for site specific studies this may be a bit large, especially for urbanized areas. A typical grid cell size used for site specific studies is 5m (up to 10m in rural areas characterised by wide and flat areas).
How have buildings been represented? Is this appropriate for the study or consistent with similar EA studies?	Buildings were represented with a Manning's n value of 0.5. For site specific models it is considered appropriate to arise the ground at the buildings footprint by 0.15m-0.2m to include the impact of the buildings on the flow direction. If the buildings footprint has not been raised it is good practise to increase the roughness to 1 to compensate.
Model performance	
Are the 1D and 2D convergence plot showing particular struggle in convergence and stability?	The Mass balance error and convergence 1D plot (screenshots) show a good model performance.
Model Inflows	
Are the updated inflows appropriate?	The inflows originally increased by 20% were updated in order to have a total increase of 35% and 70%. It is worth to notice that one of the inflows ("KEN") represents the flow produced by the River Kennet catchment. The River Kennet model has been also updated as part of this commitment. The updated "KEN" inflows were not extracted from the River Kennet model (that is based itself on the results of the River Thames at Reading model) but was updated simply rescaling the original inflows. A consistency check was done comparing the outflows from the Kennet model with the updated "KEN" inflows of the River Thames model. This comparison shows that the peak of the flow hydrograph extracted from the

	Kennet model is approximately 11% smaller than the one obtained and used for the River Thames model and therefore the approach used for the Thames inflow appear slightly conservative and for this reason acceptable. Considering the relative influence that the two models have on each other, assessing the precise inflow for the Thames model and Downstream boundary for the Kennet model would result in unreasonable working time. However a sensitivity test on the Downstream boundary was carried out in during the Kennet Model.
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TECHNICAL NOTE

Job Name: River Kennet Climate Change Hydraulic model
Job No: 37454/4001
Note No: TN001 Rev A
Date: 04th January 2017
Prepared by: Shumol Bari
Subject: **Lower Kennet Flood Study (TH641) Hydraulic Model 25%, 35% and 70% Climate Change Model Runs**

1 - Introduction

This technical note describes the hydraulic modelling carried out by PBA, to provide estimates for the 1 in 100 year (1% annual probability) plus 25%, plus 35% and plus 70% climate change flood levels for the lower River Kennet, from Tyle Mill to the confluence with the River Thames in Reading. To do this, PBA amended the current EA River Kennet hydraulic model for this reach (Lower Kennet).

The EA model along this reach was originally developed for the EA Strategic Flood Risk Mapping (SFRM) Framework in 2007. The EA model investigated a range of return period events including the (then relevant) 1 in 100 year plus 20% climate change scenario.

2 – Climate Change Planning Policy

In February 2016 the Environment Agency (EA) released new guidance on the application of climate change allowances in flood risk assessments:

<https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

The peak river flow (fluvial) climate change allowances within the new guidance replace the single 20% allowance previously applied uniformly across England and Wales. Instead a range of allowances for fluvial flooding is provided, which take account of the findings from a series of different climate change models. Through a statistical analysis of the climate change impacts from these different models, estimates across a range of fluvial climate change impacts were provided; presented in a series of climate change 'bands' for different geographic river basins.

The new climate change estimates are based on location, timescale, and across three statistical bands; 'central', 'higher central' and 'upper end'.

- The 'central' band represents the 50th percentile of the range of climate change impacts (i.e. this impact covers 50% of the range of climate change impacts).
- The 'higher central' represents the 75th percentile of the range of climate change impacts and;
- The 'upper end' represents the 90th percentile of climate change impacts.

Additionally, a H++ scenario was also considered and represents the extreme worst case climate change scenario.

As well as varying geographically (the river basin district of the site) and for the lifetime of the development or 'epoch' of climate change (2015-2039, 2040-2069 and 2070-2115); the EA guidance for selecting the appropriate climate change allowance is also subject to the Flood Zone of the site (which is independent of climate change) and the flood risk vulnerability classification of any proposed development (e.g. more vulnerable use, less vulnerable use etc.)



TECHNICAL NOTE

Table 1 below, indicates the climate change impacts for the three bands for the River Thames Basin for the different lifetimes of development.

Table 1: Climate Change – Peak River Flow Allowances

River Basin District	Future Timescale	Range of Climate Change Allowances requiring consideration (2070–2115)		
		Central	Higher Central	Upper End
Thames	2015-2039	+10%	+15%	+25%
	2040-2069	+15%	+25%	+35%
	2070-2115	+25%	+35%	+70%

The climate change allowances for future timescales, Flood Zones and vulnerability ‘uses’ for the River Thames Basin are set out in Table 2. For certain development scenarios, the EA have recommended that multiple bands are considered to assess climate change impacts across a range of allowances.

Table 2: Climate Change – Peak River Flow Allowances for River Thames Basin

River Basin District	Flood Risk Vulnerability Classification	Future Timescale	Range of Climate Change Allowances requiring consideration		
			Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Thames	Essential infrastructure	2015-2039	+15% and +25%	+25%	+25%
		2040-2069	+25% and +35%	+35%	+35%
		2070-2115	+35% and +70%	+70%	+70%
	Highly Vulnerable	2015-2039	+15% and +25%	Not Applicable	Not Applicable
		2040-2069	+25% and +35%		
		2070-2115	35% and +70%		
	More Vulnerable	2015-2039	+10% and +15%	+15% and +25%	Not Applicable
		2040-2069	+15% and +25%	+25% and +35%	
		2070-2115	+25% and +35%	+35% and +70%	
	Less Vulnerable	2015-2039	+10%	+10% and +15%	Not Applicable
		2040-2069	+15%	+15% and +25%	
		2070-2115	+25%	+25% and 35%	
	Water Compatible	2015-2039		+10%	+10%

TECHNICAL NOTE

		2040-2069	<i>No allowance to be made</i>	+15%	+15%
		2070-2115		+25%	+25%

3 - Existing Hydraulic Model

The Lower Kennet hydraulic model was completed in 2007 and is a linked 1d-2d model built using ESTRY-TUFLOW. The model was originally run using TUFLOW version 2005-02-AS and is calibrated for use in that version of the software.

The ESTRY model of the River Kennet extends from upstream of Ufton Bridge to the confluence with the River Thames in Reading.

Figure 1 shows a broad schematic of the model, with the ESTRY elements as blue arrows, the TUFLOW model domain in red and the model boundary conditions as green triangles.

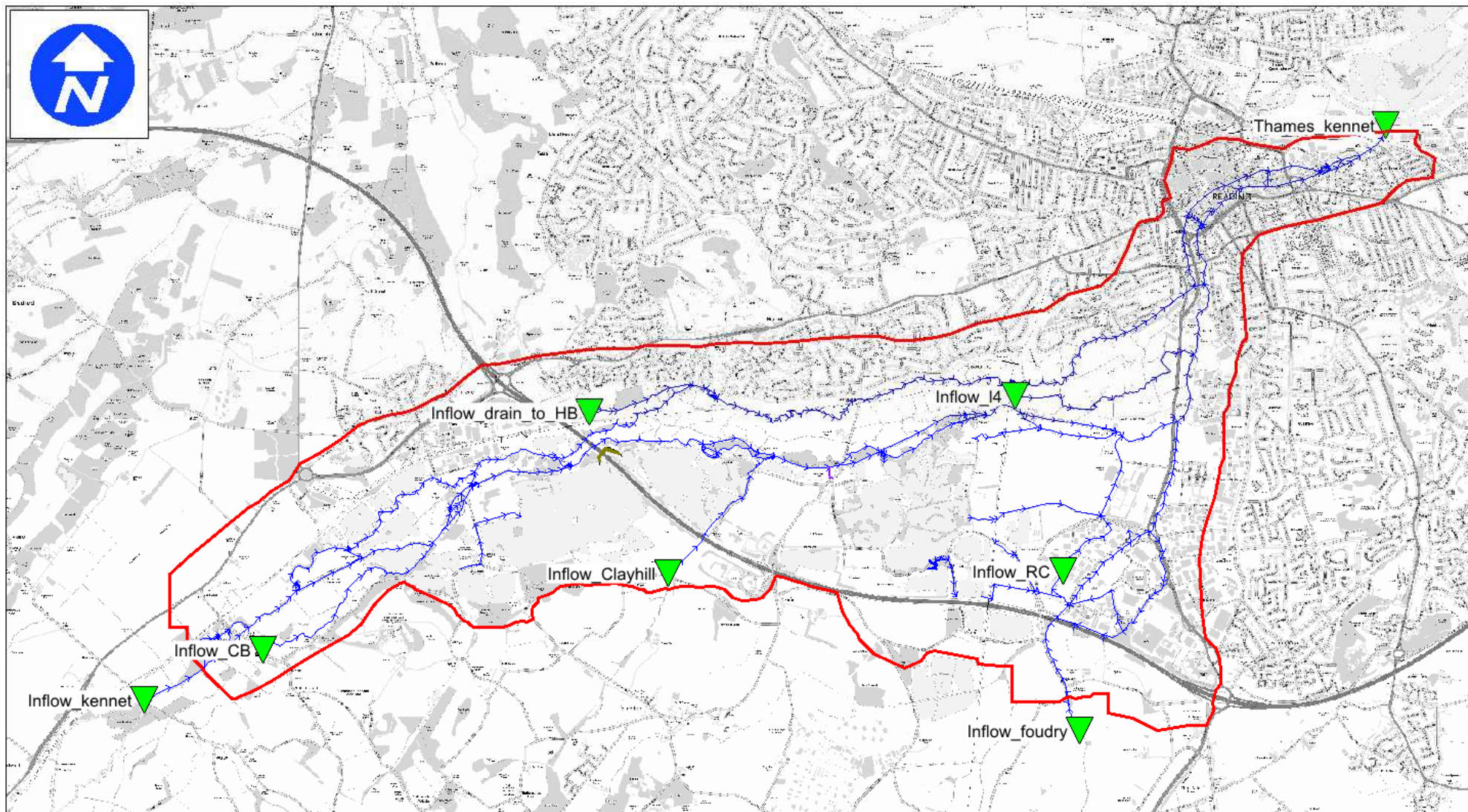
As well as the River Kennet (labelled *Inflow_Kennet* on Figure 1) the ESTRY model also contains the River Kennet tributaries, the Clay Brook (*Inflow_CB*), Clayhill Brook (*Inflow_Clayhill*), Holy Brook (*Inflow_drain_to_HB*), Green Park Stream (*Inflow_RC*) and Foundry Brook (*Inflow_Foudry*) and, an inflow into the Kennet for the catchment at Fobney Meadows (*Inflow_I4*).

The 2d TUFLOW model is a multiple domain model that extends from Tyle Mill (upstream) to the confluence with the River Thames (downstream).

The River Thames is represented as a downstream HT (stage vs time) boundary (Labelled as *Thames_kennet* in Figure 1). This boundary rises from an initial low water level to a single maximum water level which is maintained throughout the model run. This is a conservative representation of the backwater influence of the River Thames to the River Kennet.

TECHNICAL NOTE

Figure 1: Model Schematic



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The model was previously run by the EA for the following events:

- 1 in 5 year
- 1 in 10 year
- 1 in 20 year
- 1 in 100 year
- 1 in 100 year plus 20% allowance for climate change.

The model used ESTRY flow - time boundaries (QT), to apply the upstream inflows for the watercourses.

For the runs for the various modelled return periods, only the inflows for the River Kennet, the Clay Brook and Foundry Brook were modified. The remaining inflow boundaries in the model were set to constant inflows at small values; these acted as sweetening flows for the various channels.

The various peak inflows for each inflow boundary in the model are as follows;

Table 3: Peak inflows for the EA Lower Kennet model

	1 in 5 year	1 in 10 year	1 in 20 year	1 in 100 year	1 in 100 year plus 20% climate change
Kennet_inflow	58.92 m ³ /s	65.56 m ³ /s	72.34 m ³ /s	86.73 m ³ /s	95.08 m ³ /s
Clay_Brook_inflow	7.45 m ³ /s	10.95 m ³ /s	12.98 m ³ /s	18.91 m ³ /s	22.69 m ³ /s
Inflow_I4	0.40 m ³ /s	0.40 m ³ /s	0.40 m ³ /s	0.40 m ³ /s	0.40 m ³ /s
Inflow_RC	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s
Inflow_Foudry	8.18 m ³ /s	9.53 m ³ /s	13.44 m ³ /s	20.04 m ³ /s	25.71 m ³ /s
Inflow_drain_to_HB	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s
Inflow_Clayhill	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s	0.10 m ³ /s

These inflows show that Inflow_I4, Inflow_RC, Inflow_drain_to_HB and Inflow_Clayhill are constant inflows through all the modelled return periods. Only the inflows representing the upstream River Kennet, Foudry Brook and Clay Brook vary in the model.

The peak water levels used as downstream boundaries at the confluence of the River Kennet with the River Thames for each return period are shown in Table 4;

Table 4: Maximum water levels used as Downstream Boundary for the EA Lower Kennet model

	1 in 5 year	1 in 10 year	1 in 20 year	1 in 100 year	1 in 100 year plus 20% climate change
Thames_kennet	36.46 m AOD	36.59 m AOD	36.68 m AOD	36.99 m AOD	37.21 m AOD

4 – New Climate Change Allowance Runs

The version of TUFLOW which the model was calibrated to (2005-02-AS) is no longer available. To carry out the new climate change runs, the models were run using the earliest available version of TUFLOW closest to the 2005-02-AS version. This was the 2006-06-DB version and was run using the Defaults == PRE 2006-06-AA command as recommended by TUFLOW for backward compatibility for models built in earlier versions of the software.

TECHNICAL NOTE

The peak inflows in the existing EA model for the 1 in 100 year and 1 in 100 year plus 20% climate change models were checked. The differences in the inflows between the 1 in 100 year and 1 in 100 year plus climate change were not uniformly 20% (see Table 5). However, it was decided for the revised climate change modelling that a linear scaling (by 125%, 135% and 170%) of the appropriate 1 in 100 year inflows would be used for the new climate change modelling.

Only the inflows for the upstream River Kennet, Clay Brook and Foudry Brook would be scaled as these were the only inflows which were adjusted in the original EA modelling.

Table 5 indicates the scaled inflows used for the updated climate change modelling, the existing EA 1 in 100 and 1 in 100 plus 20% flows are also shown for comparison. The approximate increases between the EA 1 in 100 year and 1 in 100 year plus climate change flows are in brackets to show the different scaling between the different inflows.

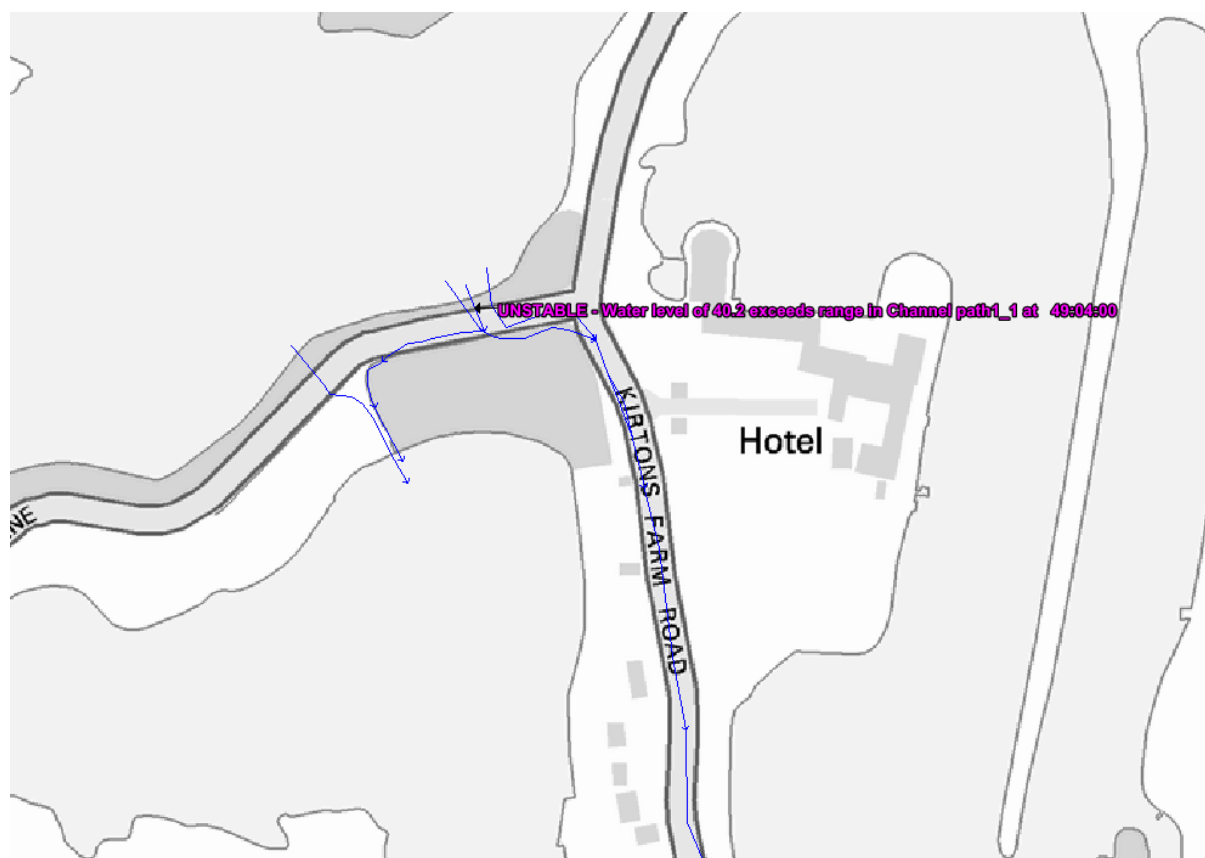
Table 5 – Updates to EA's 1 in 100 Year IED

Inflow	EA's 1 in 100 Year flow	EA's 1 in 100 + 20% Year flow	PBA 1 in 100 Year + 25% IED	PBA 1 in 100 Year + 35% IED	PBA 1 in 100 Year + 70% IED
Kennet_inflow	86.73 m ³ /s	95.08 m ³ /s (~10%)	108.41 m ³ /s	117.08 m ³ /s	147.44 m ³ /s
Clay_Brook_inflow	18.91 m ³ /s	22.69 m ³ /s (~20%)	23.64 m ³ /s	25.53 m ³ /s	32.15 m ³ /s
Inflow_Foudry	20.04 m ³ /s	25.71 m ³ /s (~28%)	25.05 m ³ /s	27.05 m ³ /s	34.07 m ³ /s

5 - Model Instability

The 70% climate change scenario caused the model to crash at the following location (Figure 2);

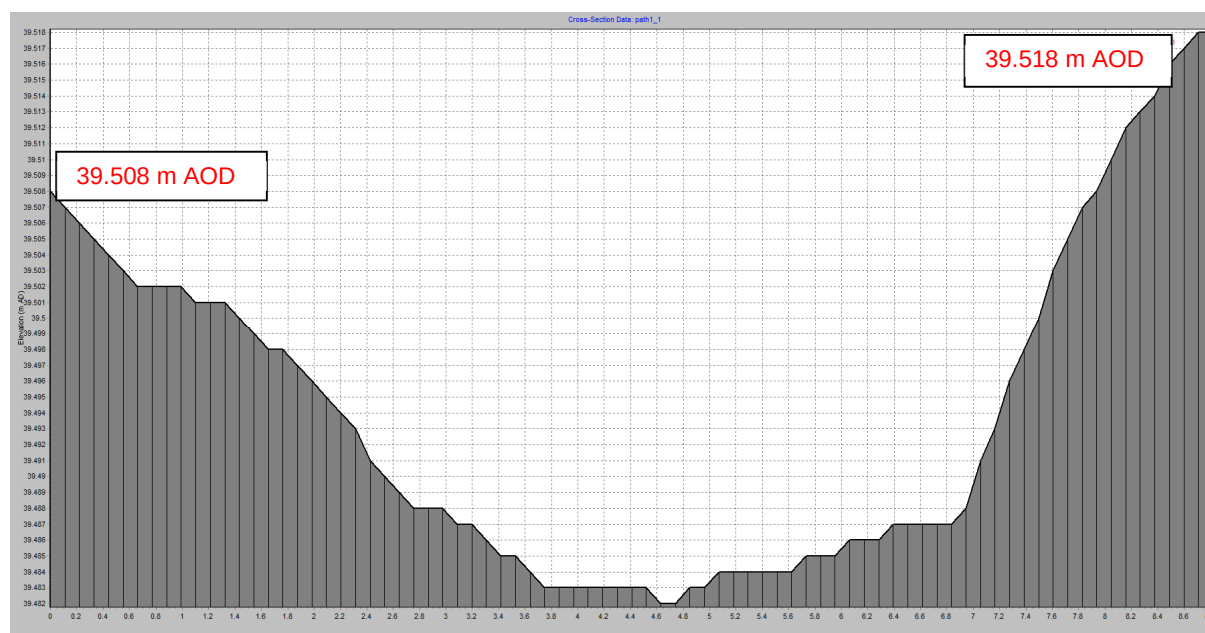
Figure 2: Location of model crash (ESTRY section Path1_1) for 1 in 100 plus 70% climate change scenario



TECHNICAL NOTE

The TUFLOW error messages indicate that the 70% climate change model caused TUFLOW to trigger a cut-off once the water level exceeded the allowable level above the maximum height of the channel section (40.2 m AOD). The channel section profile at Path1_1 is as follows (Figure 3);

Figure 3: Channel profile Path1_1

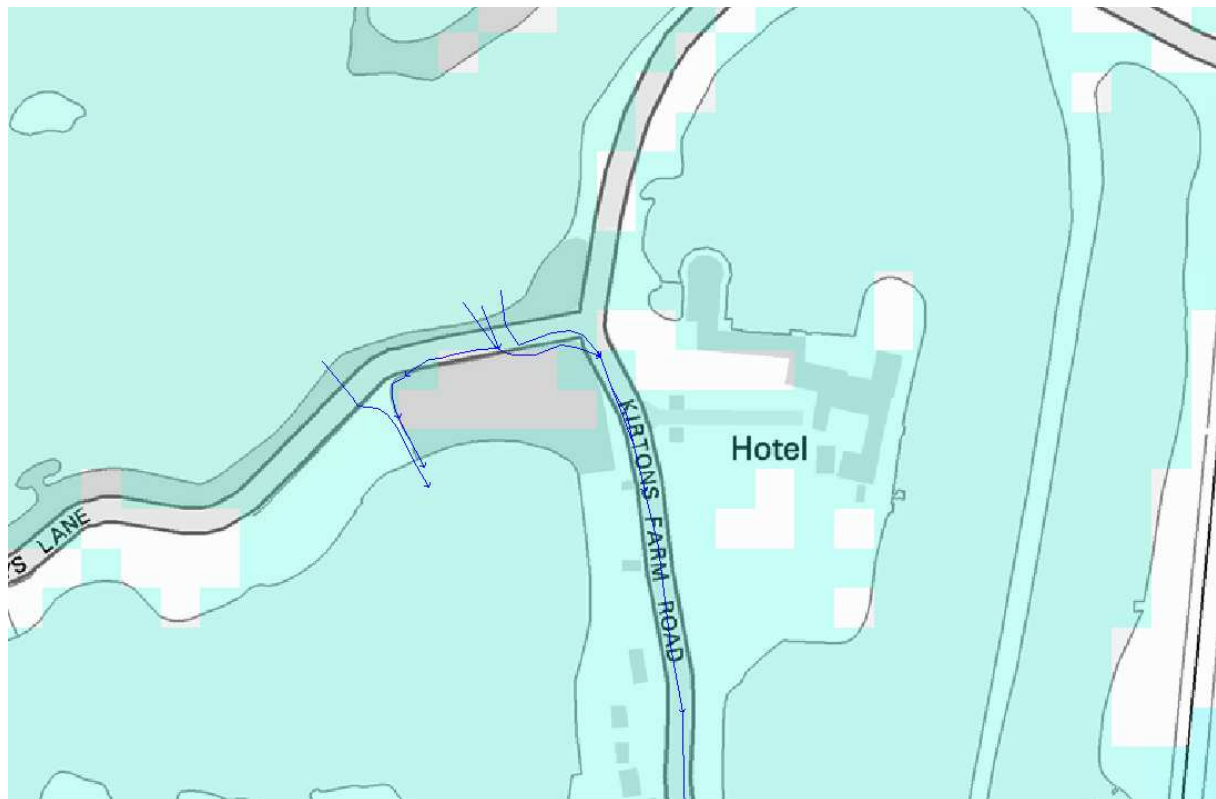


The model crashed once the water level exceeded 40.2 m AOD. To resolve this issue, the sides of channel section 'path 1_1' were extended vertically to 41 m AOD. This schematisation would increase the trigger level for this section in TUFLOW but would also artificially prevent spilling from the side of the channel in this location.

Preventing spills from this section was considered to have a minor (if any) impact on the model. Looking at the modelled flood extents, there are significant 2d flow routes around this channel. It is expected that this schematisation will not create any significant issues in terms of creating a restriction to flow by preventing side spills, as flow routes around the 1d channel section already exist.

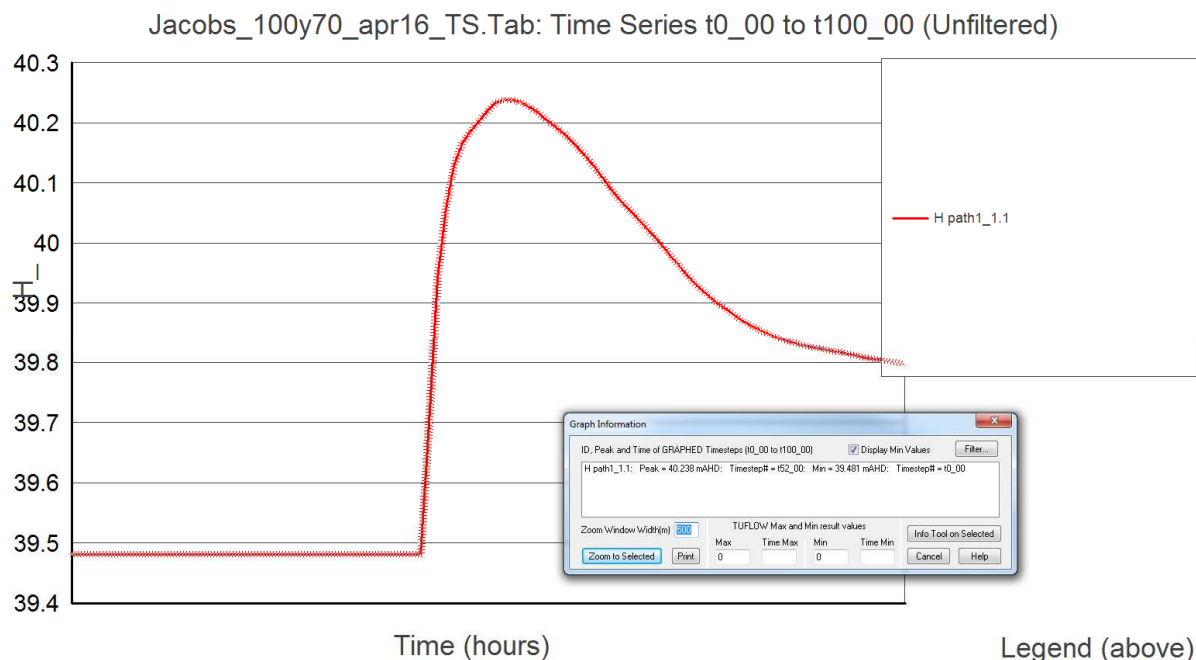
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Figure 4: 1 in 100 plus 70% flood extent at Path1_1 showing flow routes around ESTRY channel



The model results at this location are included below and indicate that the peak water level in the channel for the 100 year plus 70% climate change scenario is 40.24 m AOD. This was only 40 mm above the previous cut-off value in the model (40.2 m AOD).

Figure 5: Time series for 1 in 100 plus 70% climate change for channel Path1_1



6 - Downstream Boundary Condition

TECHNICAL NOTE

PBA have also separately updated the EA model for the River Thames for the reach including the confluence with the River Kennet (Reading Complex Change model (2011)) with the new climate change allowances. It was decided to use the updated climate change results from the River Thames model to update the downstream boundary of the Lower Kennet model to include the new climate change impacts at the downstream boundary.

When comparing the results from the EA Reading Complex Change model of the Thames (2011) to the downstream boundaries used in the existing EA Lower Kennet model (2007). It was found that the newer EA Complex Change model generated smaller water levels at the confluence of the River Thames with the River Kennet than the existing 1 in 100 plus 20% levels used in the Lower Kennet model.

Consequently, it was decided to run the models using the updated downstream levels from the River Thames Complex Change model as the principal model, but to also use the existing, higher 1 in 100 plus 20% flood level from the Lower Kennet model to act as a sensitivity test for the downstream boundary condition.

Table 3 shows the different downstream boundary conditions from the different models.

Table 3 - Maximum water levels at downstream boundaries in the model

Model	EA Lower Kennet Study model	PBA amendments to River Thames Complex Change Study model		
Event	1 in 100 plus 20%	1 in 100 plus 25%	1 in 100 plus 35%	1 in 100 plus 70%
Maximum water level at Thames Confluence/ Downstream Boundary	37.21 m AOD	36.87 m AOD	36.92 m AOD	37.14 m AOD

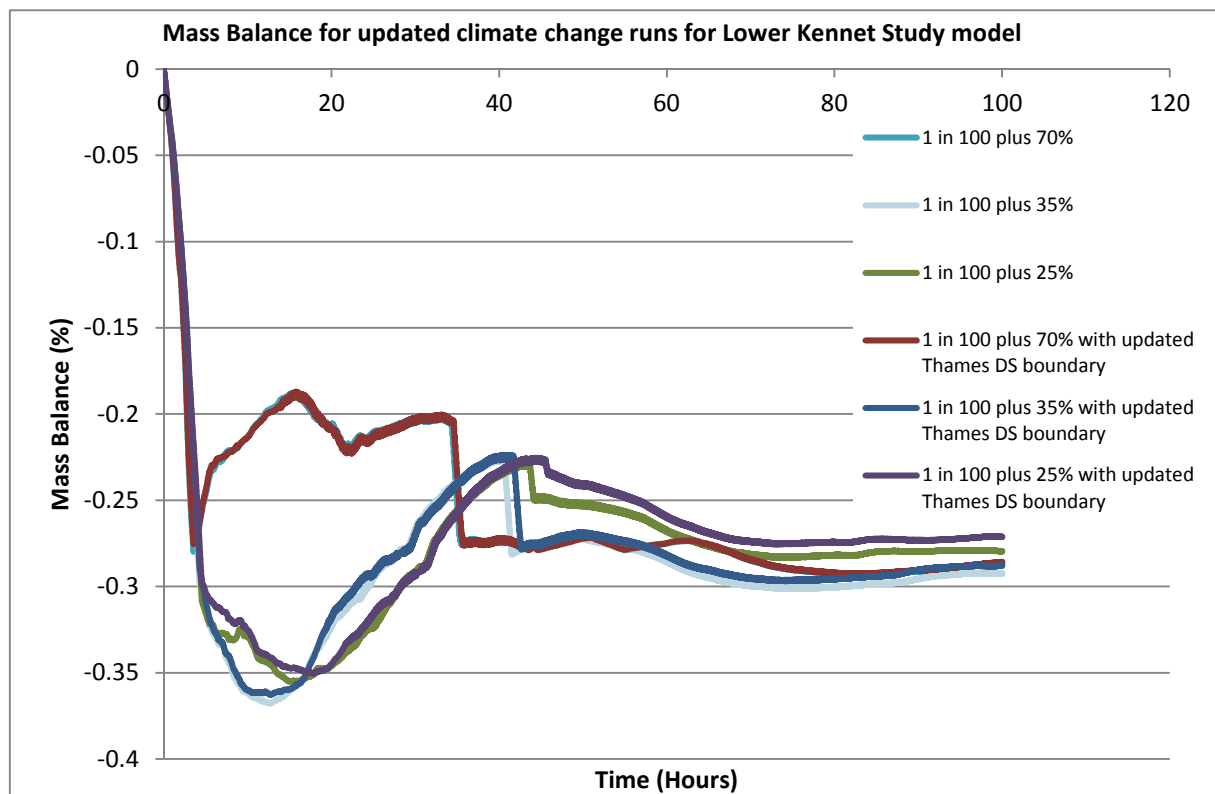
No other changes were made to the existing EA model.

7 – Model results

The model runs were stable with the 2d mass balance within the +/- 1% tolerance throughout model runs (Figure 6).

TECHNICAL NOTE

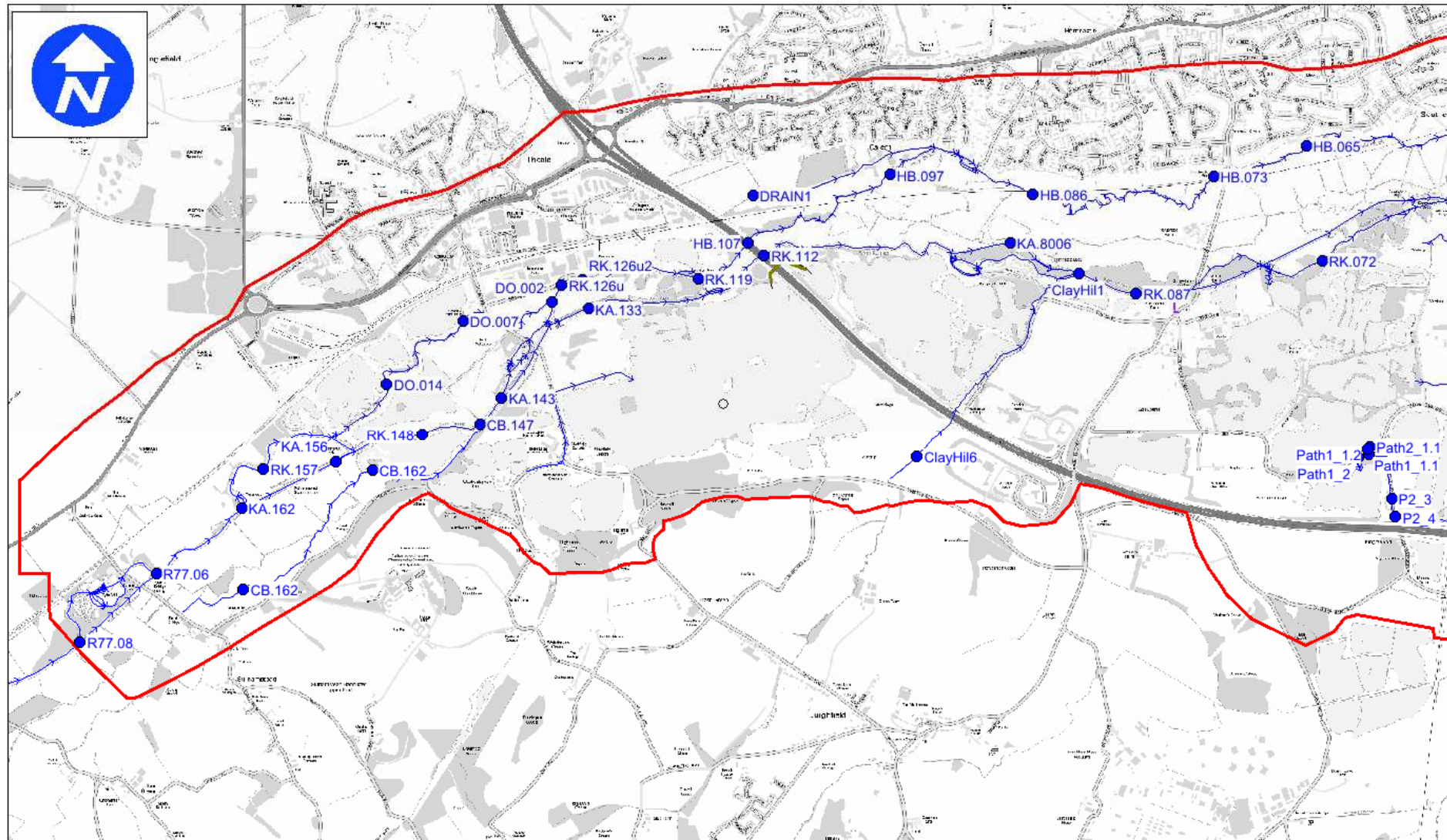
Figure 6: TUFLOW Mass Balance plots



Modelled flood levels were checked through the model and levels from each of the four scenarios run are included in Table 4. Figures 7a and 7b show the locations where the levels in Table 4 were taken.

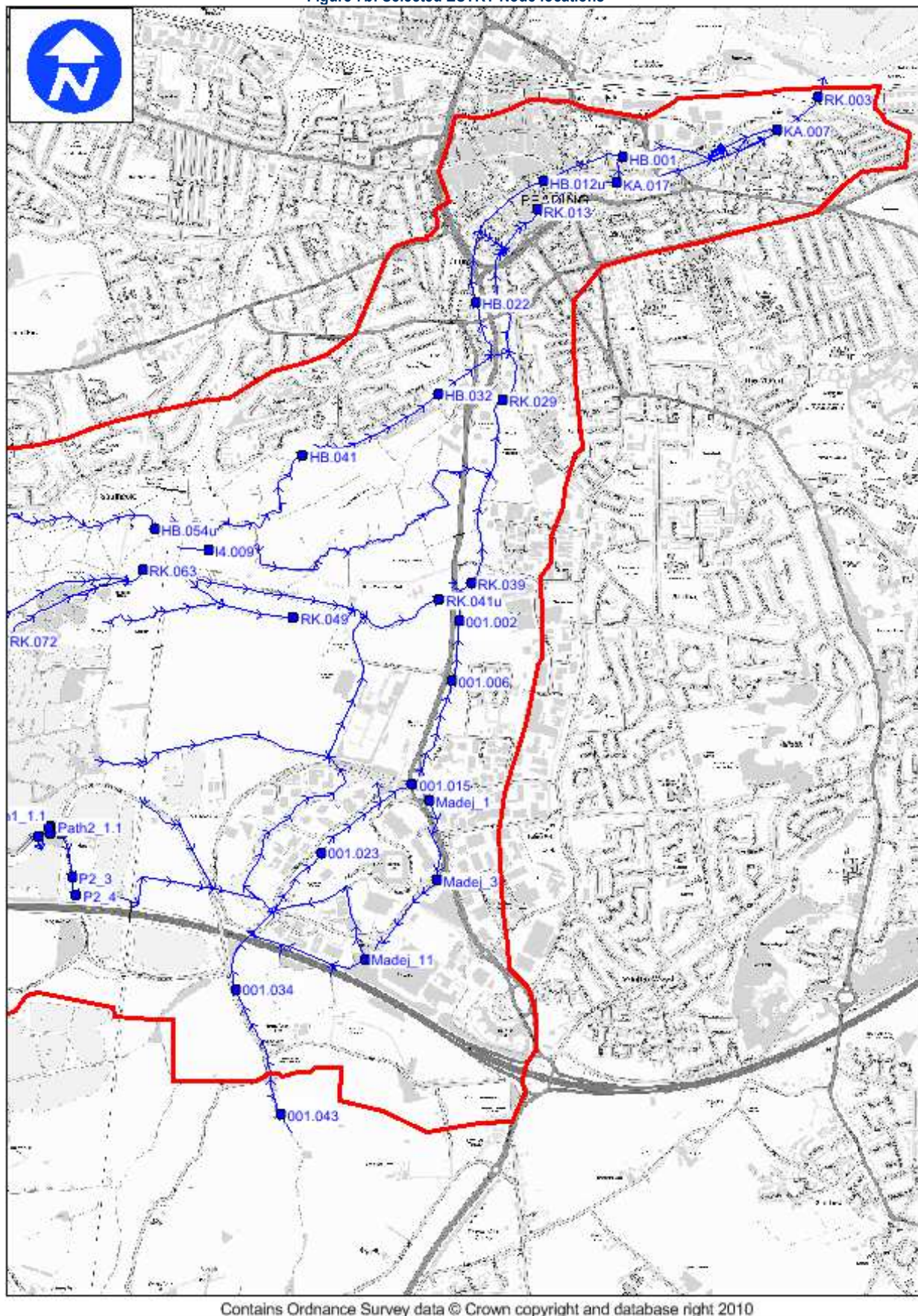
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Figure 7a: Selected ESTRY Node locations



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Figure 7b: Selected ESTRY Node locations



TECHNICAL NOTE

Table 4a – Selected ESTRY model results (levels in m AOD)

	R77.08	R77.06	ka.162	rk.157	CB.162	CB.152	cb.147	ka.156	do.014	do.007	rk.148	ka.143	ka.133
25% Thames DS	49.97	48.61	48.07	47.79	48.09	47.40	46.94	47.91	46.38	46.10	47.13	46.47	45.48
25% Existing DS	49.97	48.61	48.07	47.79	48.09	47.40	46.94	47.91	46.38	46.10	47.13	46.47	45.48
35% Thames DS	49.99	48.62	48.07	47.80	48.13	47.43	46.95	47.91	46.40	46.17	47.15	46.50	45.47
35% Existing DS	49.99	48.62	48.07	47.80	48.13	47.43	46.95	47.91	46.40	46.17	47.15	46.50	45.47
70% Thames DS	50.10	48.67	48.10	47.85	48.25	47.55	47.01	47.92	46.44	46.30	47.21	46.57	45.46
70% Existing DS	50.10	48.67	48.10	47.85	48.25	47.55	47.01	47.92	46.44	46.30	47.21	46.57	45.46

	do.002	rk.126u	rk.126u2	rk.119	rk.112	hb.107	drain 1	hb.097	hb.086	hb.071	ka.8006	ClayHil6	ClayHil1
25% Thames DS	45.63	45.56	45.45	44.76	44.35	44.42	43.25	43.48	42.29	41.66	43.54	44.98	41.96
25% Existing DS	45.63	45.56	45.45	44.76	44.35	44.42	43.25	43.48	42.29	41.66	43.54	44.99	41.96
35% Thames DS	45.70	45.63	45.51	44.83	44.41	44.48	43.32	43.50	42.34	41.71	43.54	45.10	42.01
35% Existing DS	45.70	45.63	45.51	44.83	44.41	44.48	43.32	43.50	42.34	41.71	43.54	45.10	42.01
70% Thames DS	45.87	45.81	45.69	45.02	44.58	44.65	43.47	43.54	42.47	41.85	43.55	45.25	42.13
70% Existing DS	45.87	45.81	45.69	45.02	44.58	44.65	43.47	43.54	42.47	41.85	43.55	45.25	42.13

TECHNICAL NOTE

Table 4b – Selected ESTRY model results (continued) (levels in m AOD)

	rk.087	rk.072	hb.065	hb.054	rk.063	l4.4009	rk.049	rk.041	hb.041	hb.032	rk.039	rk.029	hb.022
25% Thames DS	41.83	40.45	40.86	40.19	40.04	39.46	39.17	39.14	39.36	39.24	39.13	38.99	39.02
25% Existing DS	41.83	40.45	40.87	40.20	40.04	39.46	39.21	39.18	39.37	39.25	39.17	39.03	39.05
35% Thames DS	41.88	40.49	40.90	40.24	40.10	39.50	39.27	39.24	39.40	39.29	39.23	39.08	39.08
35% Existing DS	41.88	40.49	40.90	40.24	40.10	39.50	39.29	39.25	39.40	39.30	39.24	39.10	39.10
70% Thames DS	42.02	40.59	41.03	40.41	40.29	39.61	39.48	39.44	39.47	39.39	39.43	39.25	39.22
70% Existing DS	42.02	40.59	41.03	40.41	40.29	39.61	39.48	39.44	39.47	39.39	39.43	39.25	39.23

	rk.013	hb.012	hb.001.2	ka.017	ka.007	rk.003	001.043	001.034	001.023	001.015	001.006	001.002
25% Thames DS	38.17	38.63	37.22	37.52	37.08	36.96	40.46	39.27	39.15	39.14	39.14	39.14
25% Existing DS	38.29	38.63	37.49	37.69	37.39	37.36	40.46	39.29	39.19	39.18	39.18	39.17
35% Thames DS	38.26	38.63	37.27	37.57	37.13	37.02	40.51	39.37	39.25	39.24	39.23	39.23
35% Existing DS	38.34	38.63	37.49	37.72	37.39	37.36	40.51	39.38	39.27	39.26	39.25	39.25
70% Thames DS	38.44	38.74	37.45	37.75	37.33	37.28	40.65	39.68	39.48	39.46	39.44	39.44
70% Existing DS	38.45	38.74	37.50	37.78	37.39	37.36	40.65	39.68	39.48	39.46	39.44	39.44

TECHNICAL NOTE

Table 4c – Selected ESTRY model results (continued) (levels in m AOD)

	Madej_11	Madej_3	Madej_1	Path1_3	Path1_2	Path1_1.1	Path1_1.2	P2_4	P2_3	Path2_1.2	Path2_1.1
25% Thames DS	39.19	39.16	39.15	39.94	39.94	39.95	39.94	39.75	39.75	39.75	39.95
25% Existing DS	39.23	39.20	39.18	39.94	39.94	39.95	39.95	39.75	39.75	39.75	39.95
35% Thames DS	39.30	39.26	39.24	40.04	40.04	40.04	40.04	39.92	39.92	39.93	40.04
35% Existing DS	39.32	39.28	39.26	40.04	40.04	40.04	40.04	39.92	39.92	39.93	40.04
70% Thames DS	39.56	39.48	39.46	40.24	40.24	40.24	40.24	40.08	40.08	40.09	40.24
70% Existing DS	39.56	39.49	39.46	40.24	40.24	40.24	40.24	40.08	40.08	40.09	40.24

TECHNICAL NOTE

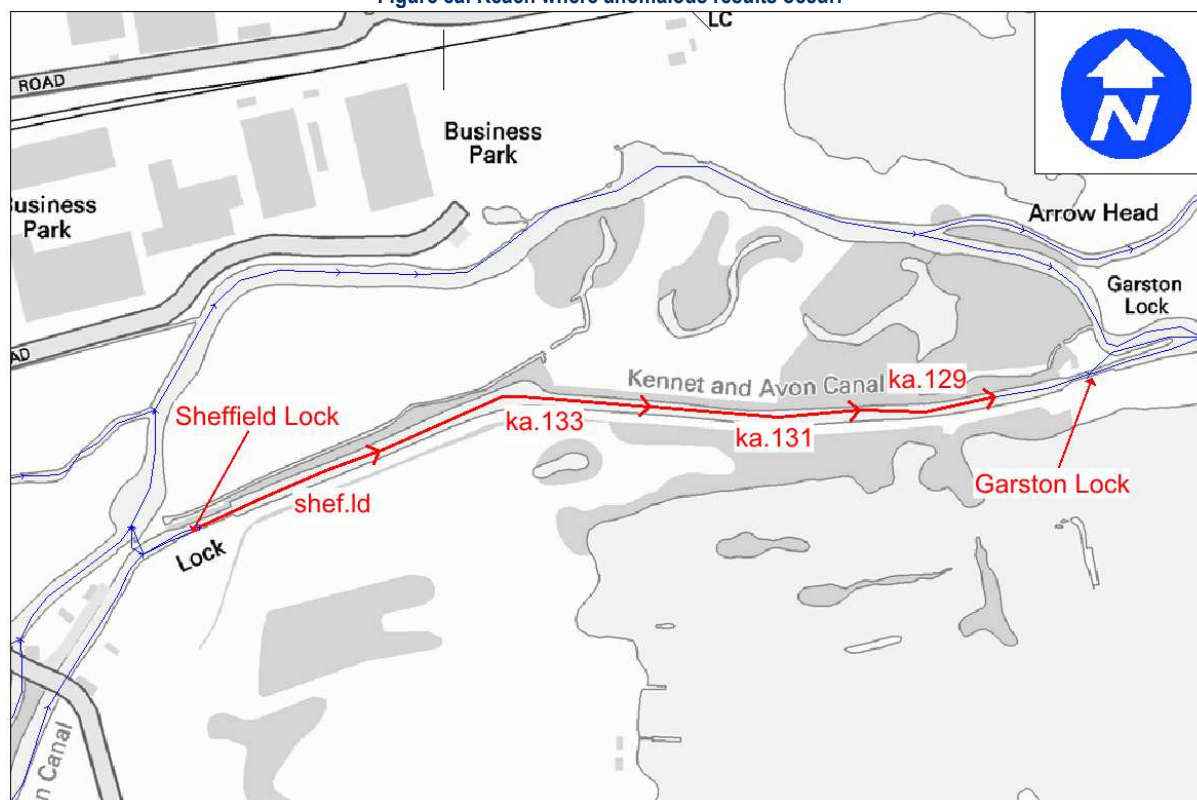
8 - Anomalous results

There is a discrepancy in the model results at between sections shef.ld, ka.133, ka.131 and ka.129, where the 35% climate change models resulted in 10mm larger flood levels than the 70% climate change scenario. This channel is the section of the Kennet and Avon Canal (K&A) between Sheffield Lock, near Theale, and Garston Lock further downstream. This section of canal runs parallel to the south of the River Kennet.

The connections between the River Kennet and the K&A canal at Sheffield Lock and Garston Lock are modelled as a weir and rectangular culvert. This schematisation is thought to represent closed lock gates at both locations. The rectangular culvert at the locks are specified as 6.09 m wide but only 10 mm in height – this is thought to allow a ‘gate leakage’ allowing a small flow through the K&A which acts as a sweetening flow to keep the model stable in this reach of the K&A. The model schematisation of this reach of the K&A suggests that this reach of the K&A will be isolated from the surrounding flood mechanisms through the assumed closure of the lock gates. Based on the current schematisation there should be minimal interaction between these watercourses in the event of a flood.

Comparison of the modelled flood levels between the existing 1 in 100 and 1 in 100 plus 20%, to the new 1 in 100 plus 35% and 70% models at this location are shown in the figures (8a-8e) below.

Figure 8a: Reach where anomalous results occur.



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Figure 8b: Selected ESTRY nodes at Sheffield Lock.

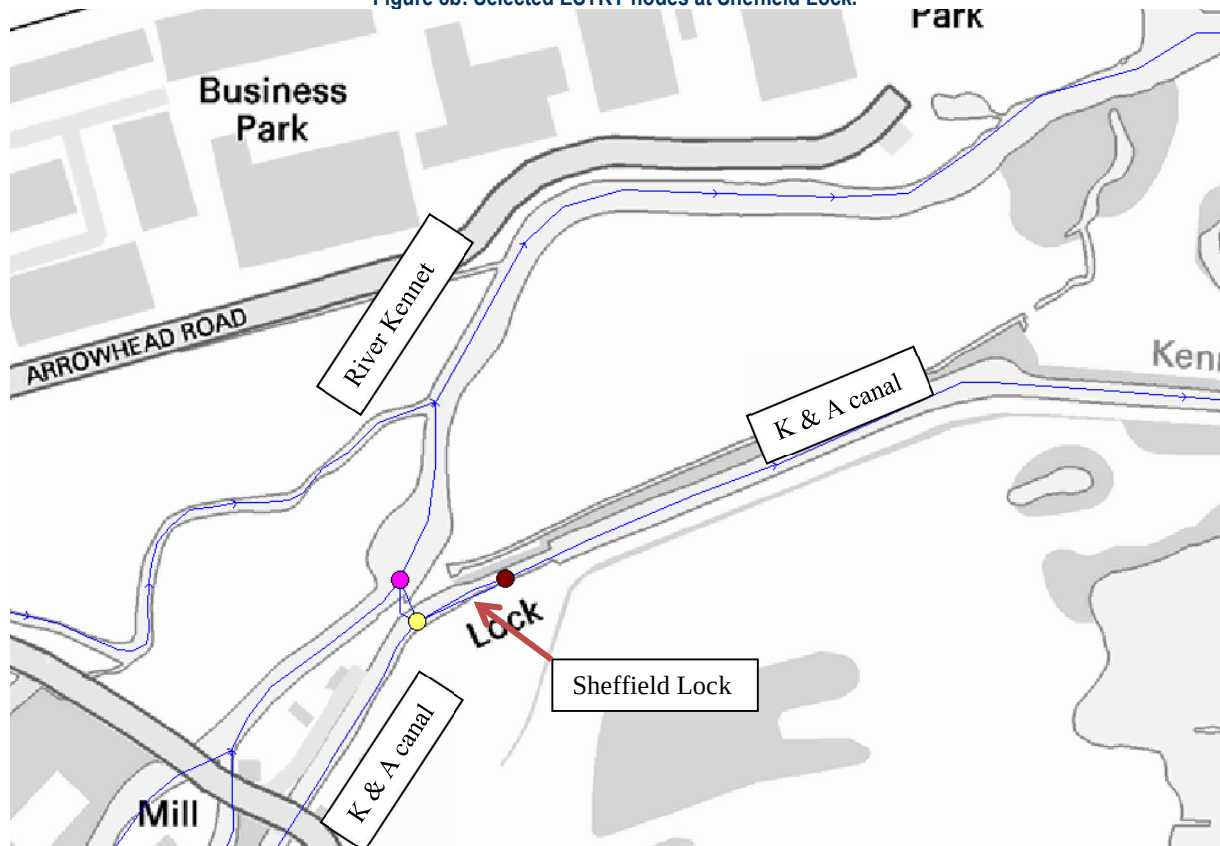


Figure 8c: ESTRY Flood Level at Yellow Node (K&A upstream of Sheffield Lock) in Figure 8b, (pink = 1 in 100 + 70%) (blue = 1 in 100 plus 35%) (yellow = 1 in 100 plus 25%) (green = 1 in 100 plus 20%) (red = 1 in 100)

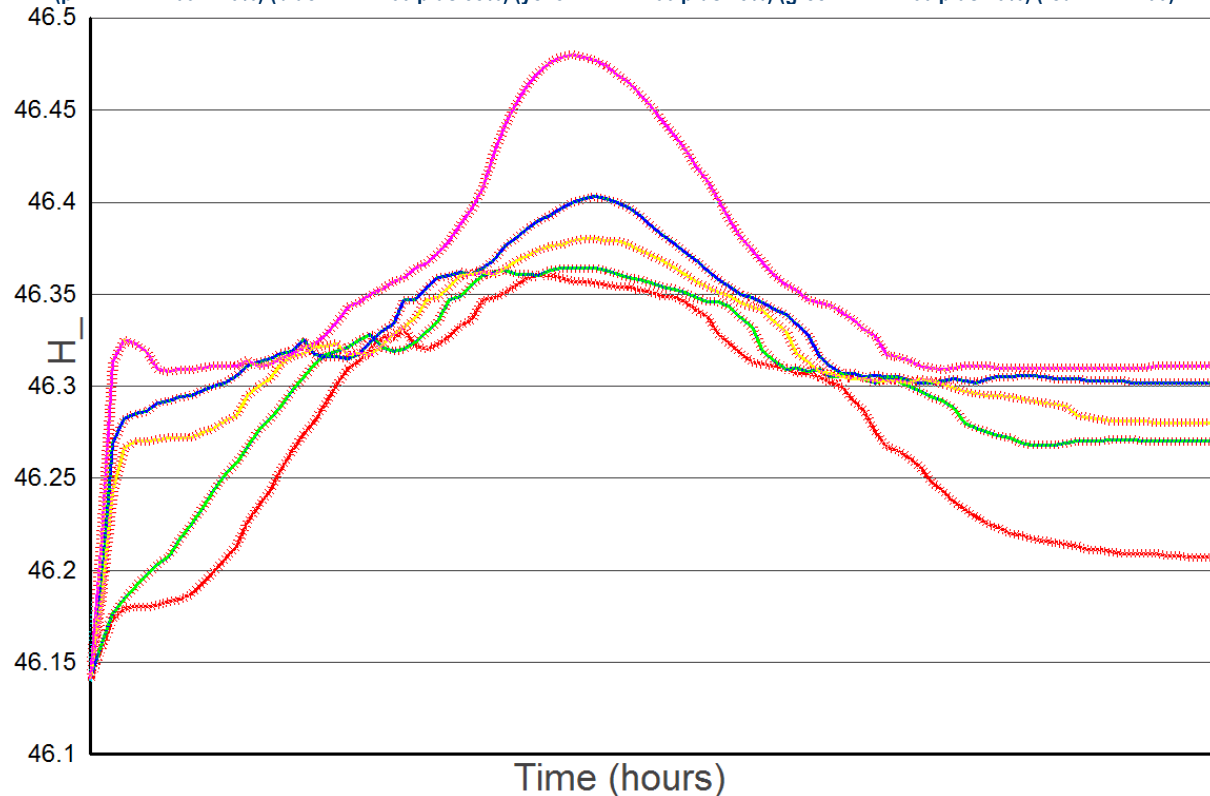
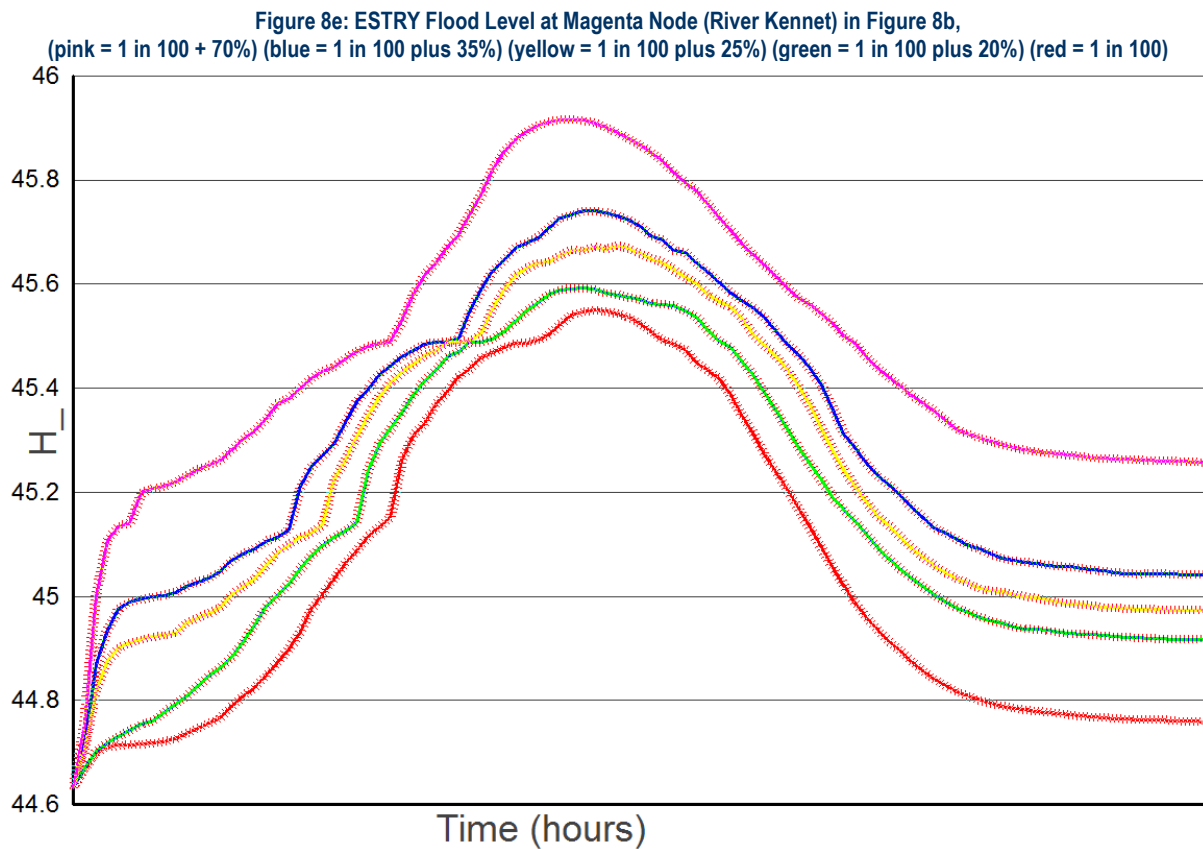
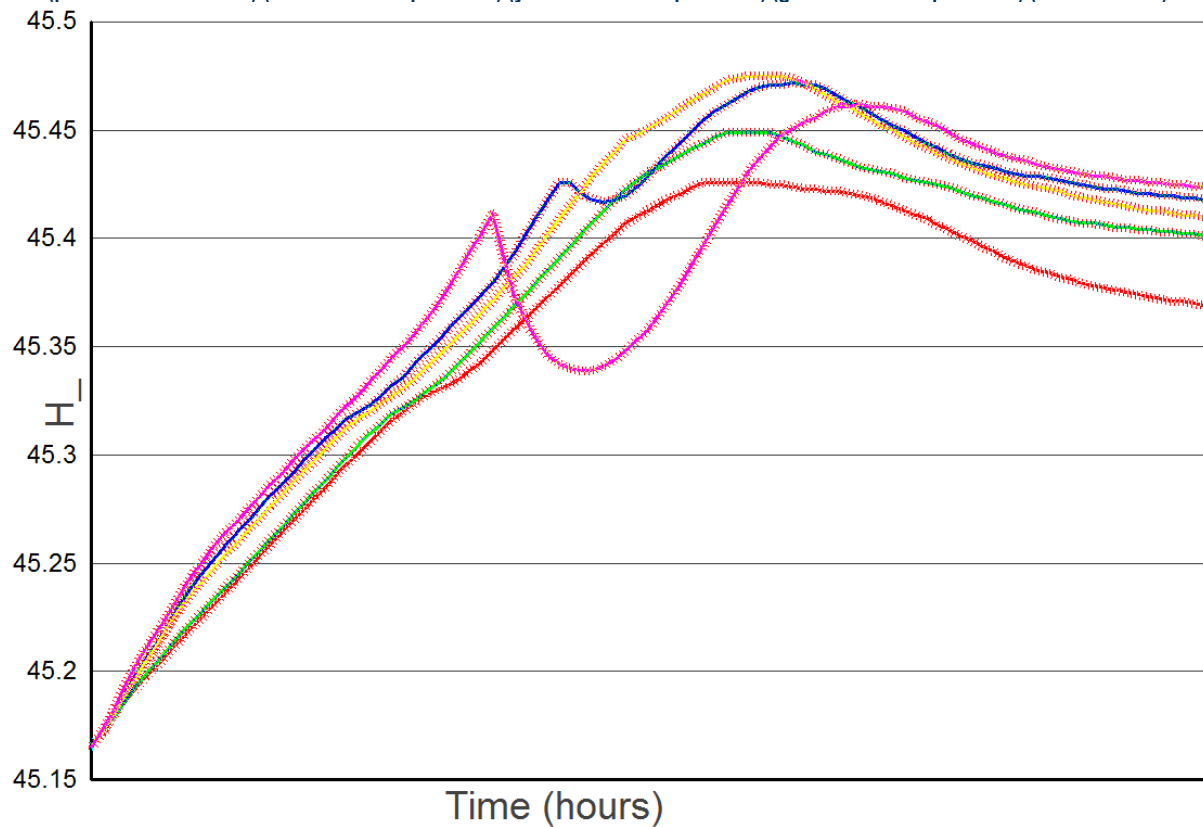


Figure 8d: ESTRY Flood Level at Brown Node (K&A downstream of Sheffield Lock) in Figure 8b,

TECHNICAL NOTE

(pink = 1 in 100 + 70%) (blue = 1 in 100 plus 35%) (yellow = 1 in 100 plus 25%) (green = 1 in 100 plus 20%) (red = 1 in 100)



TECHNICAL NOTE

Figure 8c shows a significant reduction in water level in the 1 in 100 plus 70% event – just prior to the peak in water level, in the K&A channel downstream of Sheffield Lock. This reduction looks to be the cause of the discrepancy in the peak modelled water level between the 1 in 100 plus 35% and plus 70% events. This reduction does not happen in the smaller events shown in figure 8d (1 in 100, 1 in 100 plus 20% and 1 in 100 plus 25%); and while a reduction in water level occurs at a similar time during the 1 in 100 plus 35% model, it is smaller and does not have the same impact on the peak water levels as it does the 1 in 100 plus 70% event.

Looking at the model results around this location during the modelled 1 in 100 plus 70% event, the flow upstream of Sheffield Lock is around 8.1 m³/s. This flow is then split at the confluence of the River Kennet and the K&A at Sheffield Lock, with approximately 8 m³/s continuing into the parallel reach of the River Kennet and the remaining 0.1 m³/s flows into the K&A canal. Therefore, the model does not appear to be losing any flow at this location. The small portion of the flow conveyed into the K&A at this location indicates that this channel is not a significant conveyance route in the model.

The modelled peak water level in this reach of the K&A channel is essentially a flat water surface at 45.46 m AOD along the entire 780 m reach between Sheffield and Garston locks. The water levels in the River Kennet at its confluences with the K&A at Sheffield and Garston locks, are 46.48 m AOD (approximately 1m above the K & A water level at Sheffield Lock) and 44.77 m AOD (approximately 800 mm below the K&A water level at Garston Lock). The bank levels along this length of the K&A canal are above 46 m AOD – 400 mm above the K&A water levels. The weirs at the locks are also above the peak water level, such that no spilling between the River Kennet and surrounding floodplain and this reach of the K&A occurs over these weirs, in the modelled flood events.

In the most extreme event modelled (1 in 100 year plus 70% climate change), only 0.1 m³/s flows through this reach of the K&A and no spilling into and out of this reach occurs. Therefore, this reach of the K&A is understood to have a negligible role in flood conveyance (assuming the gates are closed in a flood event, which is currently assumed in the existing EA model). Consequently as this reach of the K&A is currently modelled as having a negligible influence on the wider flood conveyance mechanisms, the discrepancies in the model at this location are understood to be isolated to this channel and do not affect the wider model.

Following the model analysis at this location, PBA has decided against altering the model to resolve this issue. It was decided that changes to the model to resolve this issue could increase the role of this reach of the K&A in flood conveyance beyond what has been assumed in the existing EA model. PBA has considered it more appropriate to accept the limitation in the modelled flood levels along this reach of the K&A, than change the current assumptions on the conveyance mechanisms along this reach of the K&A canal. Any future work near this reach of the K&A would be important would necessitate future investigation.

The sensitivity testing of the downstream boundary conditions indicates that the modelled flood levels are only dependent on the downstream water level for a short reach upstream of the confluence of the River Kennet to the River Thames. The impact of the different tidal boundary for the 1 in 100 plus 70% climate change event becomes less than 10 mm approximately 1500m upstream of the River Thames confluence.

9 – EA model review

PBA submitted the proposed climate change modelling (+35% and +70% only as the 25% climate change modelling was not undertaken in time for submission for review) for both the River Kennet and the River Thames (Reading Complex Change model – used for the downstream boundary of the River Kennet model) for review by the EA in August 2016. The EA provided review notes in December 2016.

The comments in the review note were not significant and generally were regarding the suitability of the model cell sizes and the schematisation of buildings. These elements were unchanged from the base EA models for the River Kennet and the River Thames and were considered appropriate as part of the original EA modelling.

TECHNICAL NOTE

As the modelling undertaken was to update to the existing EA models to the new climate change allowances, it was not considered appropriate to revisit the underlying assumptions in the model. The result of any amendments to cell sizes or building schematisation (either through topographic or Manning's n roughness changes) would alter the existing modelled results and have a knock-on effect to the EA Flood Zones. On this basis any changes to cell sizes or building schematisation would not be appropriate given the proposed uses of the updated climate modelling (the modelling undertaken by PBA is not intended to be appropriate for a Flood Zone review).

The EA comments for both the models are appended to this note.

10 – Conclusion

The EA released new guidance on flood risk assessment climate change allowances in February 2016. This new guidance requires consideration of the +25%, +35% and +70% ('Higher Central' and 'Upper End') climate change estimates for 'More Vulnerable' uses in Flood Zones 2 and 3a within the Thames River Basin, including the River Kennet.

PBA have run the EA's current Lower Kennet Study hydraulic model for the new 1 in 100 plus 25%, 1 in 100 plus 35% and 1 in 100 plus 70% climate change scenarios.

The changes made by PBA to the current EA model were to scale the appropriate model inflows by 25%, 35% and 70%, and also to rerun each climate change scenario with updated downstream boundaries. The downstream boundary information was taken from PBA's updated climate change runs of another EA model; the Reading Complex Change model, which is the relevant EA model for the reach of the Thames at the confluence of the River Kennet.

In order to address a model stability issue associated with the new increased climate change flows (specifically the +70% scenario); an existing section of the model was also modified with vertical walls added. This issue was thought to be associated with a TUFLOW error cut-off being exceeded by the large increase in flow from the 70% scenario. The model results at this section were checked and found to be stable and the inclusion of vertical walls to prevent glass walling at this section were not thought to have a significant impact the model results in this area.

The new climate change models were also run using the existing EA model downstream boundary, as a sensitivity test to changes in the downstream boundary.

The model produced coherent results for the majority of the model, but there was a discrepancy in a short reach (780 m) of the K&A canal between Sheffield Lock and Garston Lock. This discrepancy resulted in marginally larger results for the 1 in 100 year +25% (15 mm) and the 1 in 100 year +35% (10 mm) events when compared to the 1 in 100 year +70% event. After investigating the model at this location, the anomalous results were isolated to this short reach of channel of the K&A. This channel was assessed as having a negligible role in flood conveyance in the existing EA model schematisation.

Given the minor significance of this channel to flood conveyance in the wider model, this issue was considered to be of negligible significance to the wider model results. The modelled impacts were localised to this reach of the K&A canal.

Therefore it was decided to caveat the updated climate change modelling of the EA River Kennet model as appropriate for use, apart from this short reach of the K & A canal.

The appropriate climate change allowance for a given development should be based on the scenarios outlined in table 2 of this report (i.e. dependent on proposed vulnerability use and lifetime of development).

Of the suite of models carried out by PBA (the 1:100 AP event plus 25%, 35% and 70% climate change, using the updated downstream boundary conditions and the existing EA downstream boundary for sensitivity testing); the models with the updated downstream boundaries are the most appropriate for use. These relate to the results labelled '25% Thames DS', '35% Thames DS' and '70% Thames DS' in Table 4. These models include the most appropriate downstream boundary - generated using the

TECHNICAL NOTE

current EA model of the River Thames at the confluence to the Lower Kennet, with the new EA revised climate change guidance.

The flood levels from plus 25%, 35% and 70% climate change scenarios modelled by PBA, are appropriate for use for the 'Higher Central' and 'Upper End' climate change estimates for 'More Vulnerable' use in Flood Zones 2 and 3a, up to 2115. The use of these flood levels would provide conservative flood levels for any other combination of lower vulnerability use and shorter lifetime of development.

TECHNICAL NOTE

Appendix

- Environment Agency ISIS/TUFLOW MODEL UPDATE review
Kennet Climate Change update (dated 19/07/2016)
- Environment Agency ISIS/TUFLOW MODEL UPDATE review
Thames Climate Change update (dated 04/07/2016)

DOCUMENT ISSUE RECORD

Technical Note No	Rev	Date	Prepared	Checked	Reviewed (Discipline Lead)	Approved (Project Director)
37454/4001/TN001	-	19.07.16	SB	AH	RF	SM
37454/4001/TN001	A	04.01.17	SB – Added plus 25% climate change results and addressed EA review comments (Dec 2016)	AH	AH	DH

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ISIS/TUFLOW MODEL UPDATE Review

Study: Kennet Climate Change update

Consultant: PBA

Model date: 19/07/2016

Modeller: Shumol Bari

This is an existing EA model and only the Climate Change approach has been changed (New February 2016 Policy applied).

Model Domain and DTM	
Check location and dimension of 2D grid. is the domain large enough/does it tie-in to high ground?	The New climate change policy requires an increase in inflows of 35% and 70% (instead of 20%). The significant inflow increase produces an increase in flood extent introducing the risk of glasswalling (as the code area was based on the 20% increase for climate change flood extent).
What is grid cell size? Is this suitable for the study?	25m cell size was used. Considered the purpose of using the model for site specific studies this may be a bit large, especially for urbanized areas. A typical grid cell size used for site specific studies is 5m (up to 10m in rural areas characterised by wide and flat areas).
How have buildings been represented? Is this appropriate for the study or consistent with similar EA studies?	Buildings were not represented in the model.
Model performance	
Are the 1D and 2D convergence plot showing particular struggle in convergence and stability?	The Mass balance error plots show good model performance.
Model Inflows	
Are the updated inflows appropriate?	The inflows originally increased by 20% were updated in order to have a total increase of 35% and 70%. <i>See Thames at reading climate change update model review.</i>