

TECHNICAL NOTE

Job Name: Reading Complex Change Hydraulic Model- updated climate change to 2115
Job No: 40388
Note No: TN001 Rev A
Date: 30th January 2017
Prepared by: Shumol Bari
Subject: **Reading Complex Change Hydraulic Model 25%, 35% and 70% Climate Change Model Runs**

1 - Introduction

This technical note summarises the hydraulic modelling carried out by Peter Brett Associates LLP (PBA) to apply the most recent updates climate change allowances (Flood Risk Assessments: Climate Change Allowances (February 2016)) for the River Thames, from Mapledurham to Sonning. This modelled used the current EA River Thames hydraulic model for this reach (Reading Complex Change model (2011)) and updated the 1 in 100 (1%) Annual Probability (AP) event to consider the plus 25%, 35% and 70% climate change allowances for fluvial flow.

The EA model along this reach was originally developed for the Reading Complex Change Project (2011) which investigated a range of return period events including the (previously relevant) 1 in 100 AP 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 allowances table within the new guidance replaces the single 20% allowance previously used for England and Wales. Instead a range of allowances for fluvial flooding are 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 for a range of fluvial climate change impacts were provided, in a series of climate change 'bands'.

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

- The 'central' band represents the 50th percentile of the range of climate change impacts (i.e. 50% of the range of climate change impacts were below this level).
- 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 considered as representing 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 (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 and the flood risk vulnerability classification of the proposed use.

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Table 1 below indicates the climate change impacts for the three bands for the River Thames Basin for the different future timescales.

Table 1: Climate Change – Peak River Flow Allowances

River Basin District	Timescale in the future	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 recommend that several 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%	Development Not permitted	Development Not permitted
		2040-2069	+25% and +35%		
		2070-2115	35% and +70%		
	More Vulnerable	2015-2039	+10% and +15%	+15% and +25%	Development Not permitted
		2040-2069	+15% and +25%	+25% and +35%	
		2070-2115	+25% and +35%	+35% and +70%	
	Less Vulnerable	2015-2039	+10%	+10% and +15%	Development Not permitted
		2040-2069	+15%	+15% and +25%	

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		2070-2115	+25%	+25% and 35%	
	Water Compatible	2015-2039	No allowance to be made	+10%	+10%
		2040-2069		+15%	+15%
		2070-2115		+25%	+25%

3 - Existing Hydraulic Model

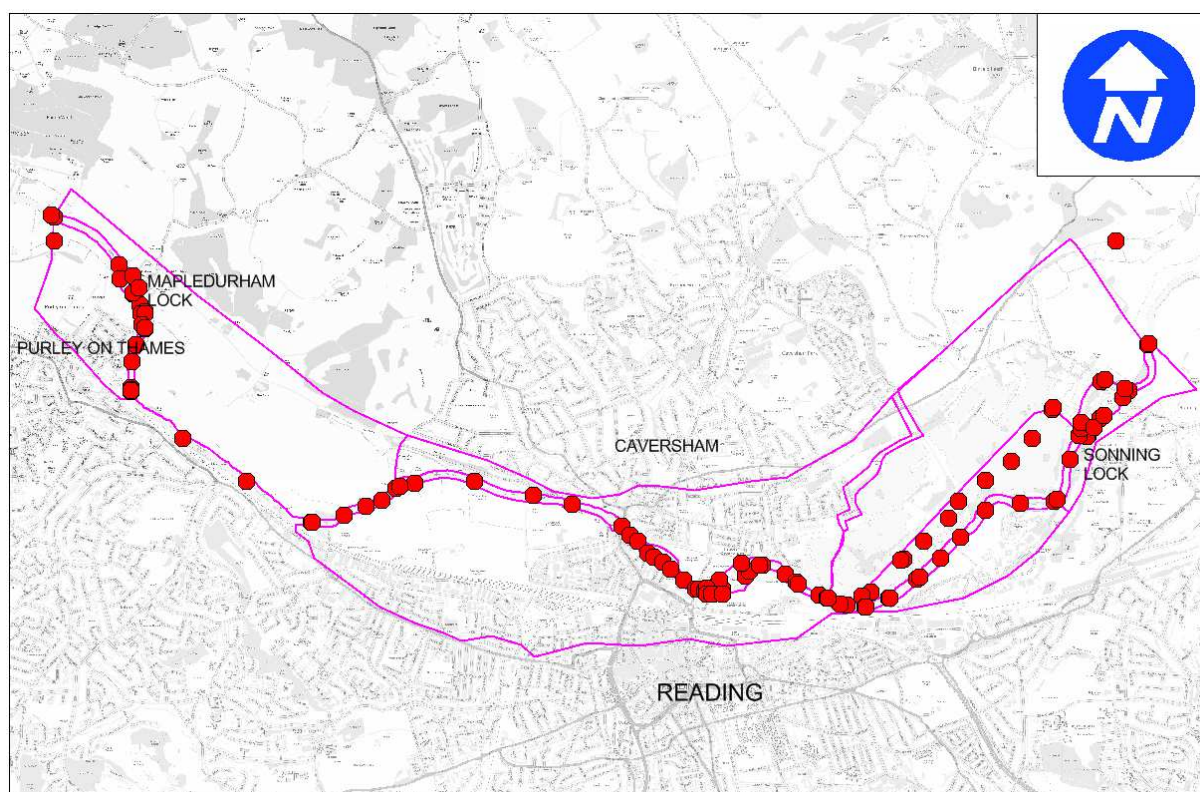
The EA's Reading Complex Change hydraulic model was completed in 2011. The model is a linked 1d-2d model built using ISIS-TUFLOW and was run using TUFLOW version 2009-07-AD-iSP and ISIS version 3.3

The 1d ISIS model extends from upstream of Whitchurch Lock to downstream of Marsh Lock, (the EA Reading Complex Change hydraulic modelling report indicates the model extends from Whitchurch Lock to Shiplake Lock approximately 4.4km upstream of actual downstream end of the ISIS model).

The 2d TUFLOW model was a multiple domain model which is attached to the 1d ISIS model from upstream of Mapledurham Lock to downstream of Sonning Lock, past Sonning Bridge (Figure 1).

The model 2d domains varied between 10 m grid and 30 m grid sizes connected with 2d-2d links.

Figure 1: 2d model domains



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

- 1 in 5 year (1 in 5 or 20% AP)
- 1 in 20 year (1 in 20 or 5% AP)
- 1 in 100 year (1 in 100 or 1% AP)
- 1 in 100 year (1 in 100 or 1% AP) plus 20% allowance for climate change.
- 1 in 1000 year (1 in 1000 or 0.1% AP)

The model used IED files to provide the appropriate inflow boundaries for each modelled event. Each model run used a single IED file.

Each event also has a specific ISIS model DAT file, however the models have been compared in ISIS and there are no changes between the ISIS models (including the boundary conditions) for each event.

The model boundary conditions in the ISIS model are listed below; they have been separated into inflow boundaries in the IED file; the inflow boundaries in the model DAT file and the downstream boundaries in the model DAT file:

Inflow boundaries in the IED files are:

- 38.002a – Main Thames Inflow
- KEN – River Kennet inflow
- 34b.053q – River Loddon catchment (minus Berry and Folley) inflow

Other Inflow boundaries in the ISIS model DAT file (unchanged by the IED file):

- PANGM1 – dummy inflow into Pangbourne meadow
- 37.PANG
- B40a

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- FLOOD1

Downstream boundaries:

- SC14 – fixed Stage time boundary
- SB02 – fixed Stage time boundary
- H_Dummy – fixed Stage time boundary
- BER3 – fixed Stage time Boundary
- 32.096 – Flow Stage boundary at downstream of Thames model.

The Other Inflow boundaries in the ISIS model DAT files do not vary between the different ISIS model .DAT files used for each event. It is assumed that these constant inflows were used in the EA models as sweetening flows.

The main downstream boundary condition 32.096 is a flow stage curve located at the downstream end of the Thames model. The EA hydraulic modelling report indicates that this boundary condition is located away from the main area of interest of the EA study (Reading) such that *'...the assumed (downstream) boundary condition does not affect water levels in the study area'*.

There are no 2d inflow boundary conditions in the model.

4 – New Climate Change Runs

The ISIS run (IEF) files for the EA models indicated that a single IED file was used for each modelled return period. The boundary conditions in the DAT files did not change between the different return periods modelled. Consequently, only the inflows in the IED file are understood to have changed for the EA model runs.

To carry out the new climate change runs, the 1 in 100 AP IED file ('run_100yr.ied') was used as the base boundary condition file. The IED file only altered three of the inflow boundaries. It was assumed that the remaining fixed inflows in the model would not be affected as they did not vary between the EA 100 AP and 100 AP + CC (20%) ISIS model (DAT) files.

The model report for the Reading Complex Change Project Hydraulic Modelling Report v 2 (June 2011) did not indicate what the individual constant inflows (PANGM1, 37.PANG, B40a and FLOOD1) in the DAT files were.

The 'run_100yr.ied' IED file, used for the 1 in 100 AP run, was compared against the EA 100 AP plus 20% 'run_100yr+CC.ied' IED file. It was found that the raw inflow data (hydrographs) was (in general) scaled by 1.2 (as opposed to using a flow multiplier to scale the 100 AP hydrograph) to provide the 20%.

Inflow 34b.053q was scaled to be marginally less than 1.2 (1.2 scaling should be 92.28 m³/s as opposed to the 92.18 m³/s in the IED file), but it was considered that this discrepancy was negligible (~0.1% difference) and there was no information to explain this discrepancy in 34b.053q in the Complex Change hydraulic modelling report.

Rather than scaling the raw inflow data for the new 25%, 35% and 70% climate change a flow multiplier was used to scale the 'run_100yr.ied' inflows. This was considered acceptable as the only difference between the 'run_100yr.ied' and the 'run_100yr+CC.ied' was the scaling by 1.2 of the raw data – the minor discrepancy in 34b.053q apart.

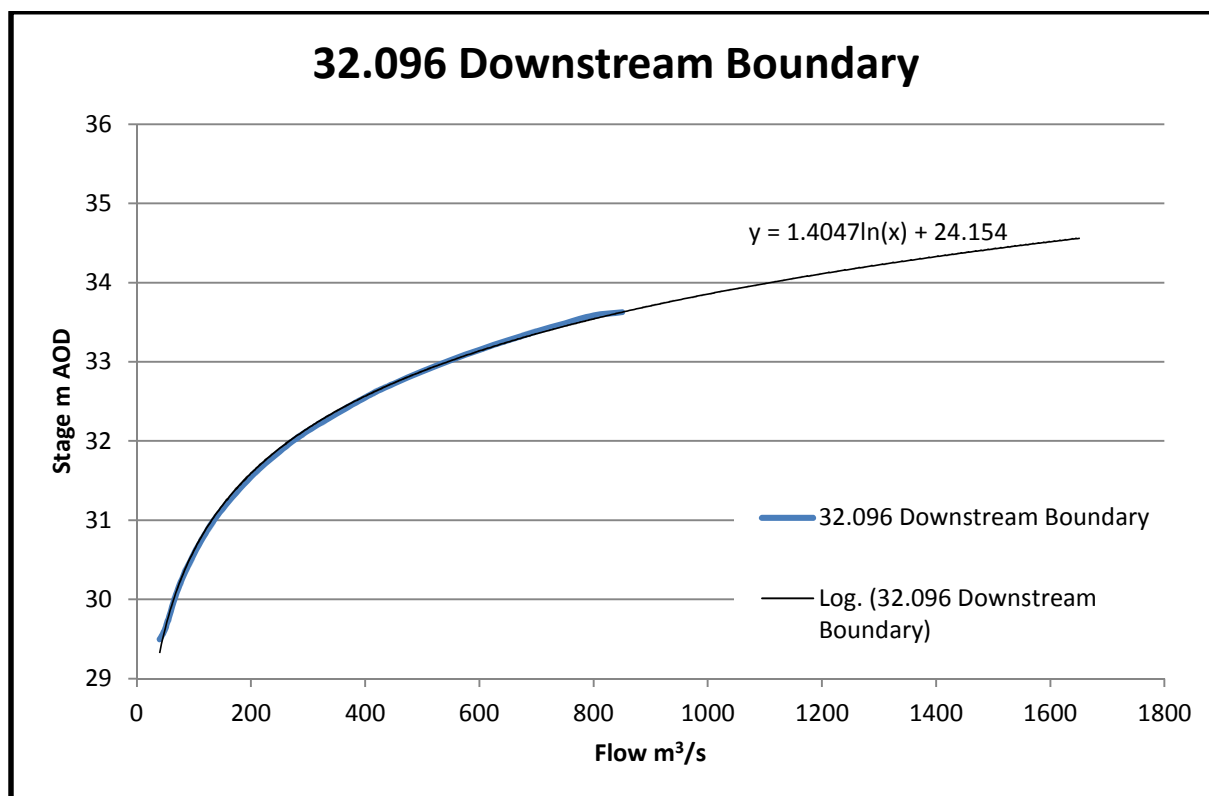
Table 2 – Updates to EA's 1 in 100 AP IED

Inflow	EA's 1 in 100 AP + 20% IED	PBA 1 in 100 AP + 25% IED	PBA 1 in 100 AP + 35% IED	PBA 1 in 100 AP + 70% IED
38.002a	Scaled from 375 to 450	1.25 flow multiplier	1.35 flow multiplier	1.70 flow multiplier
KEN	Scaled from 62.7 to 75.3	1.25 flow multiplier	1.35 flow multiplier	1.70 flow multiplier
34b.053q	Scaled from 76.9 to 92.18	1.25 flow multiplier	1.35 flow multiplier	1.70 flow multiplier

The 70% climate change scenario caused the downstream water level to exceed the downstream Flow Stage boundary (32.096) and triggered the initial model runs to crash – data exceeded limit of rating curve. This downstream boundary curve was extrapolated to provide the additional flow data for greater flood levels to allow the 70% climate change runs to be completed.

The curve was extrapolated using Excel (Figure 2), with the existing Flow vs. Stage data points being fitted to a log curve. The Flow vs. Stage curve in the existing model extended to flow values of 850 m³/s which allowed for water levels of 33.63 m AOD. The Flow vs. Stage curve was extended to provide flow data to 1900 m³/s which allowed for the downstream boundary to reach water levels of approximately 34.75 m AOD.

Figure 2: extrapolation of 1d downstream boundary (32.096)



The correlation between the Flow vs. Stage data from the existing model and the equation for the extrapolated Flow vs. Stage curve is good, and consequently the extrapolated downstream boundary curve is considered an appropriate extension to the existing downstream boundary, assuming that the Flow vs. Stage relationship at the downstream boundary continues to follow the same trend.

The model was run using the same parameters as the existing Complex Change model.

No other changes were made to the EA's existing model.

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5 – Model Results

The model runs were both stable with the 2d mass balance within the +/- 1% tolerance throughout both model runs (Figure 3).

The ISIS convergence plots for all the model runs were also good, with the only period of poor convergence occurring as the model initialised (Figure 4).

Figure 3: TUFLOW Mass Balance plots

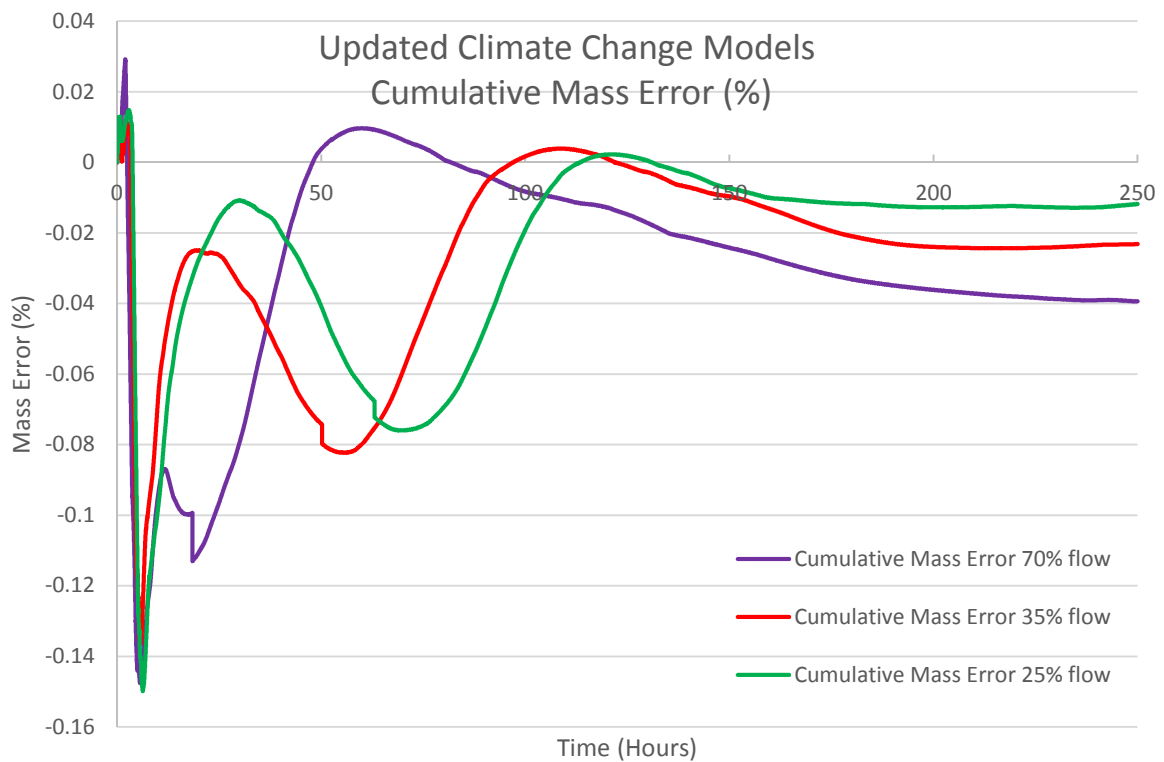
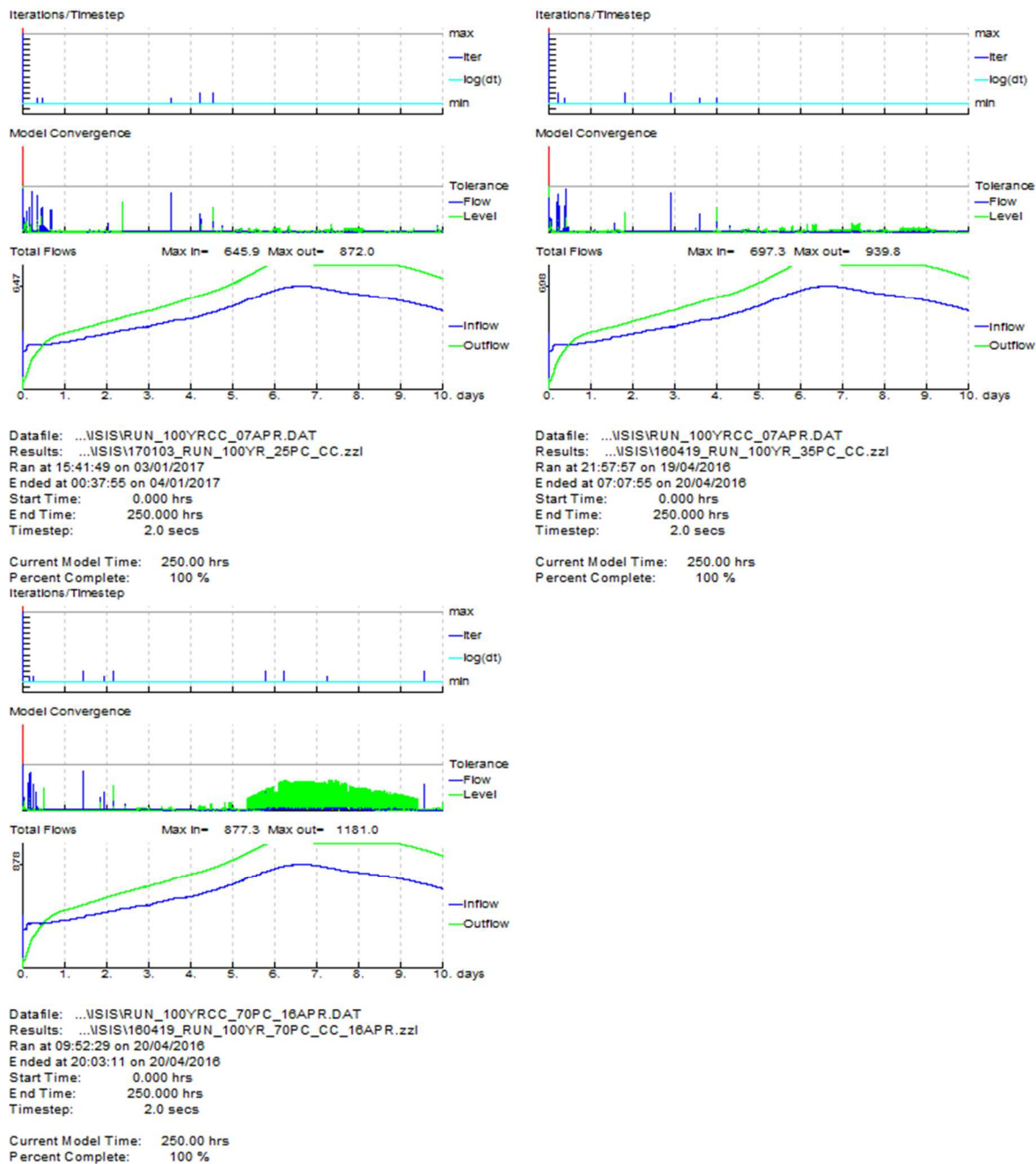


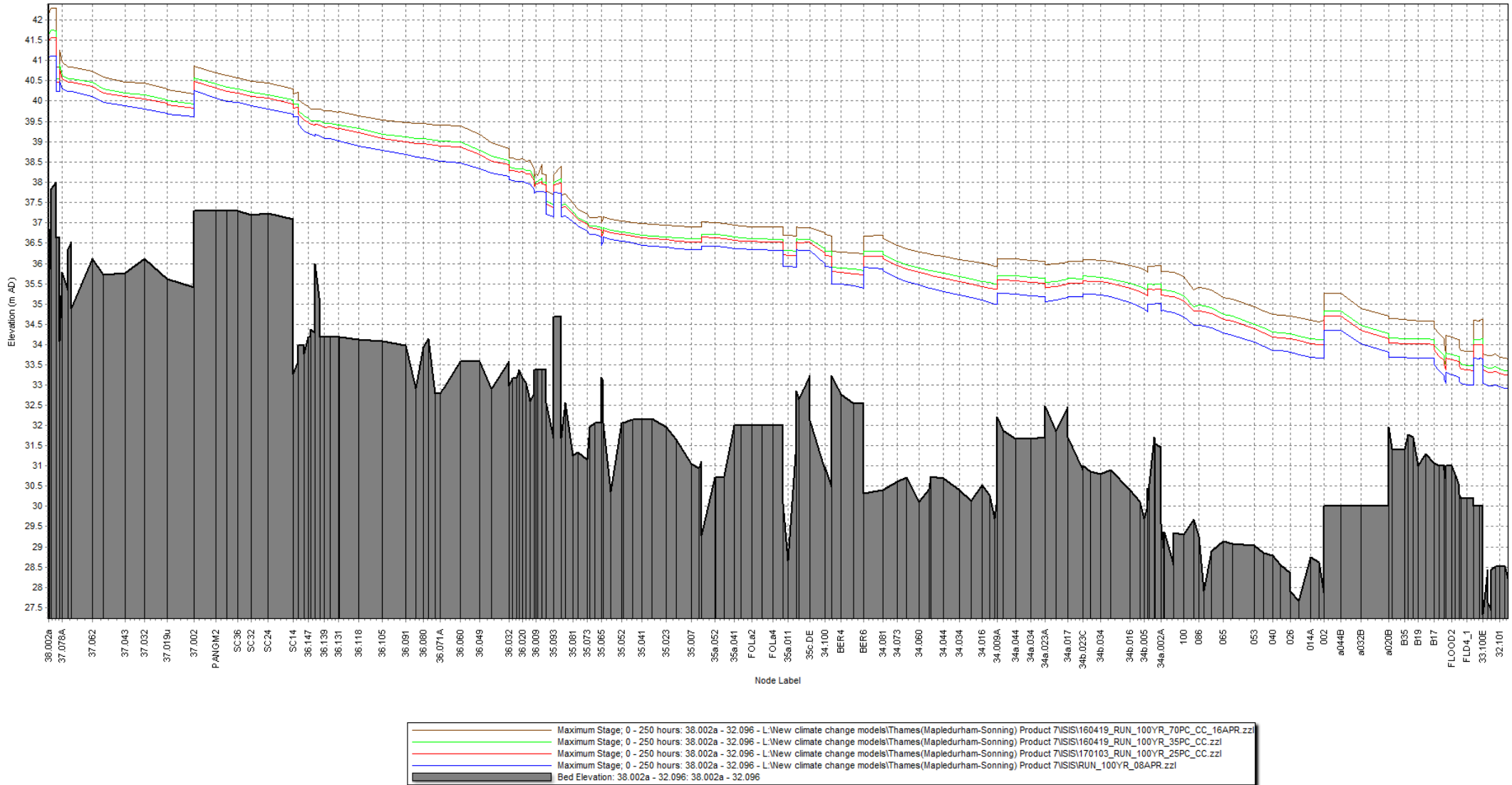
Figure 4: ISIS Convergence plots



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Figure 6: 1 in 100 event (blue) with 25% (red), 35% (green) and 70% (brown) ISIS maximum water levels

Long Section: 38.002a - 32.096 - Maximum Stage; 0 - 250 h.



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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

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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.

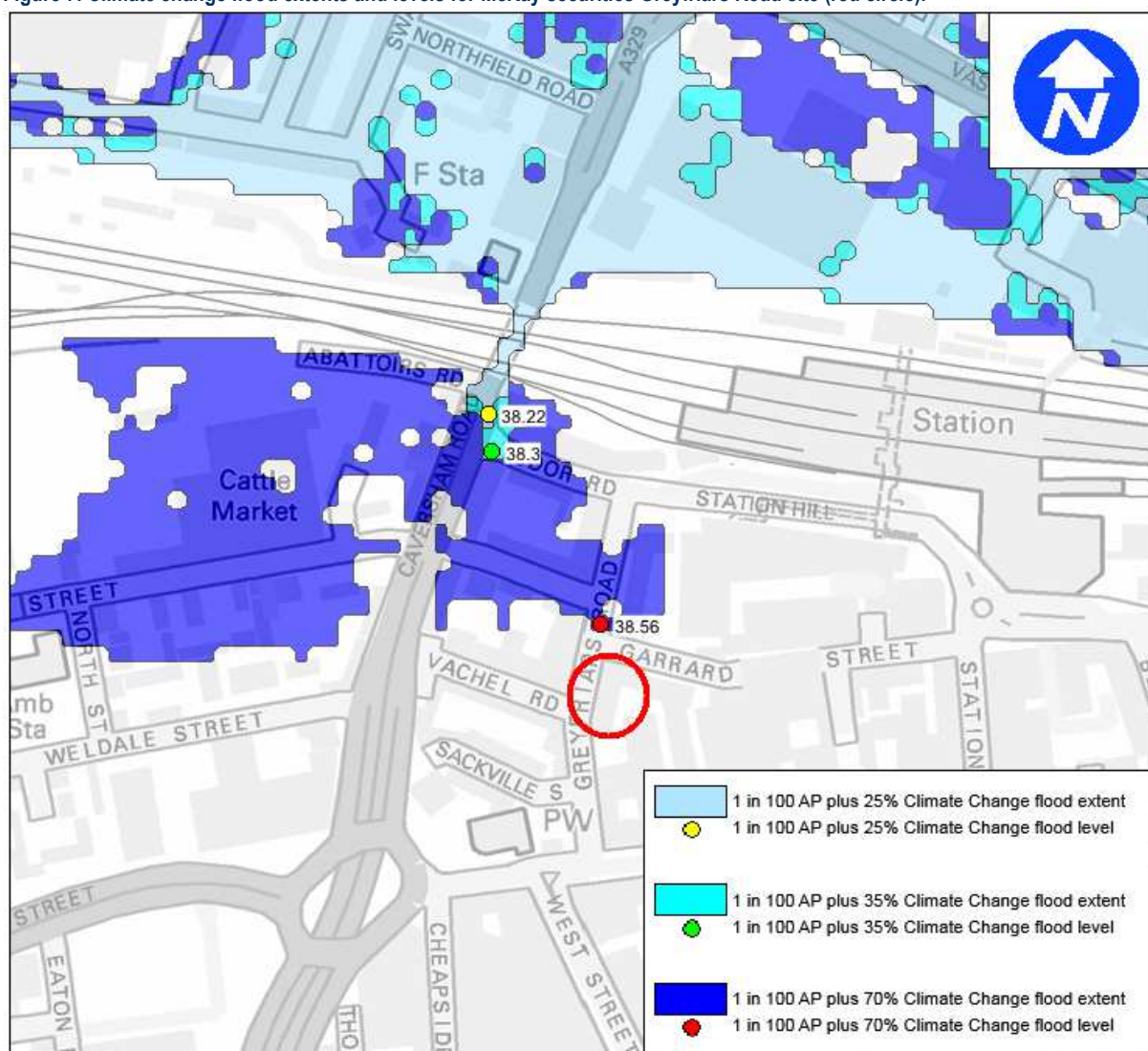
8 – Site specific information

This updated climate change model was used to generate flood extents and flood levels for the McKay securities site on Greyfriars Road, Reading, Berkshire.

The site is shown on the EA online flood maps as being located in Flood Zone 1, outside the 1 in 1000 AP event.

The climate change flood extents to 2115 for the site are shown in figure 7 below with relevant flood levels.

Figure 7: Climate change flood extents and levels for McKay securities Greyfriars Road site (red circle).



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The site is shown to be outside the modelled climate change flood extents to 2115.

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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Peter Brett Associates LLP Caversham Bridge House Waterman Place, Reading Berkshire RG1 8DN

T: +44 (0)118 950 0761 +44 (0)118 959 7498 E: reading@peterbrett.com