OFFICIAL SENSITIVE

TECHNICAL REPORT

Oxford Flood Alleviation Scheme Modelling Report

Prepared for

Environment Agency

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Document History

This document has been issued and amended as follows:

Version	Date	Description	Created by	Checked by	Approved by	Document Number
1.0	14-06-16	Draft for comment	CW	LL	Draft	RE-N-000124
2.0	22-07-16	Report update including outline design sensitivity, Q95 flow assessment and response to EA comments	CW	LL	LL	As above.
3.0	09-09-16	Updated following Stage 5 peer review. Submitted as final.	CW	LL	LL	As above.
4.0	03-11-16	Revision to climate change section. Re-submitted as Final	LL	LL	LL	As above

Introduction

The Environment Agency (EA) WEM Lot 3 project Oxford Flood Alleviation Scheme (FAS) was awarded to CH2M in April 2015. The project included updating the existing (2014) hydraulic model to support development of the outline FAS design. The project follows on from the Oxford Flood Strategy and the more recent (2014) initial assessment of the preferred (near term) option, which in this case was a flood diversion channel from Botley Road to Downstream of Sandford Lock.

1.1 Model Area

The model area covers approximately 19km of the River Thames from its confluence with the River Evenlode to downstream of Sandford Lock (NGR 445465, 209310 to 453880, 198620) and the River Cherwell from the A40 to its confluence with the River Thames (NGR 451540, 209970 to 452010, 205100). Figure 1 details the model extent and key locations. Figure 2 details the key rivers and streams in Oxford.

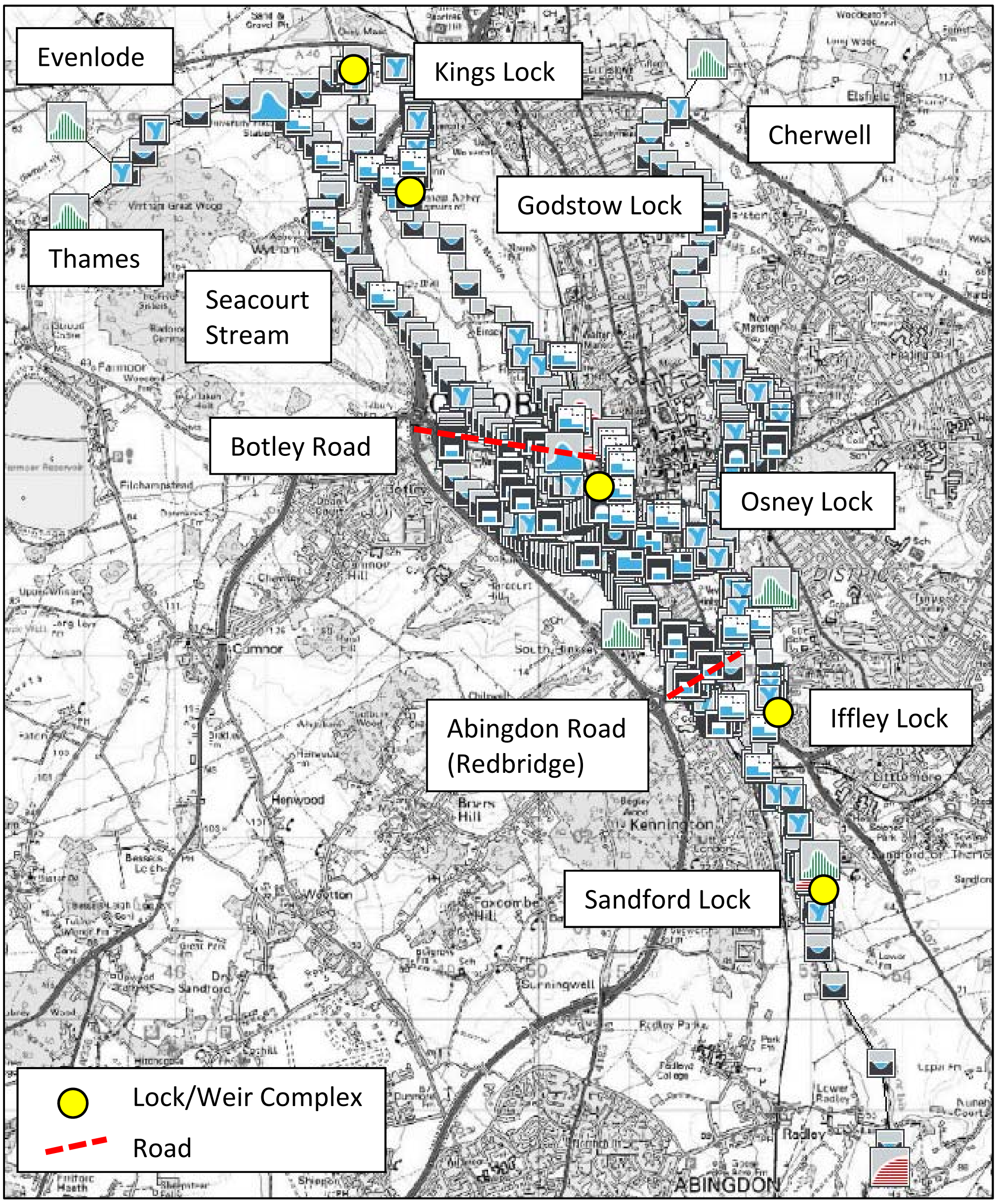

Figure 1: Model extent and key locations

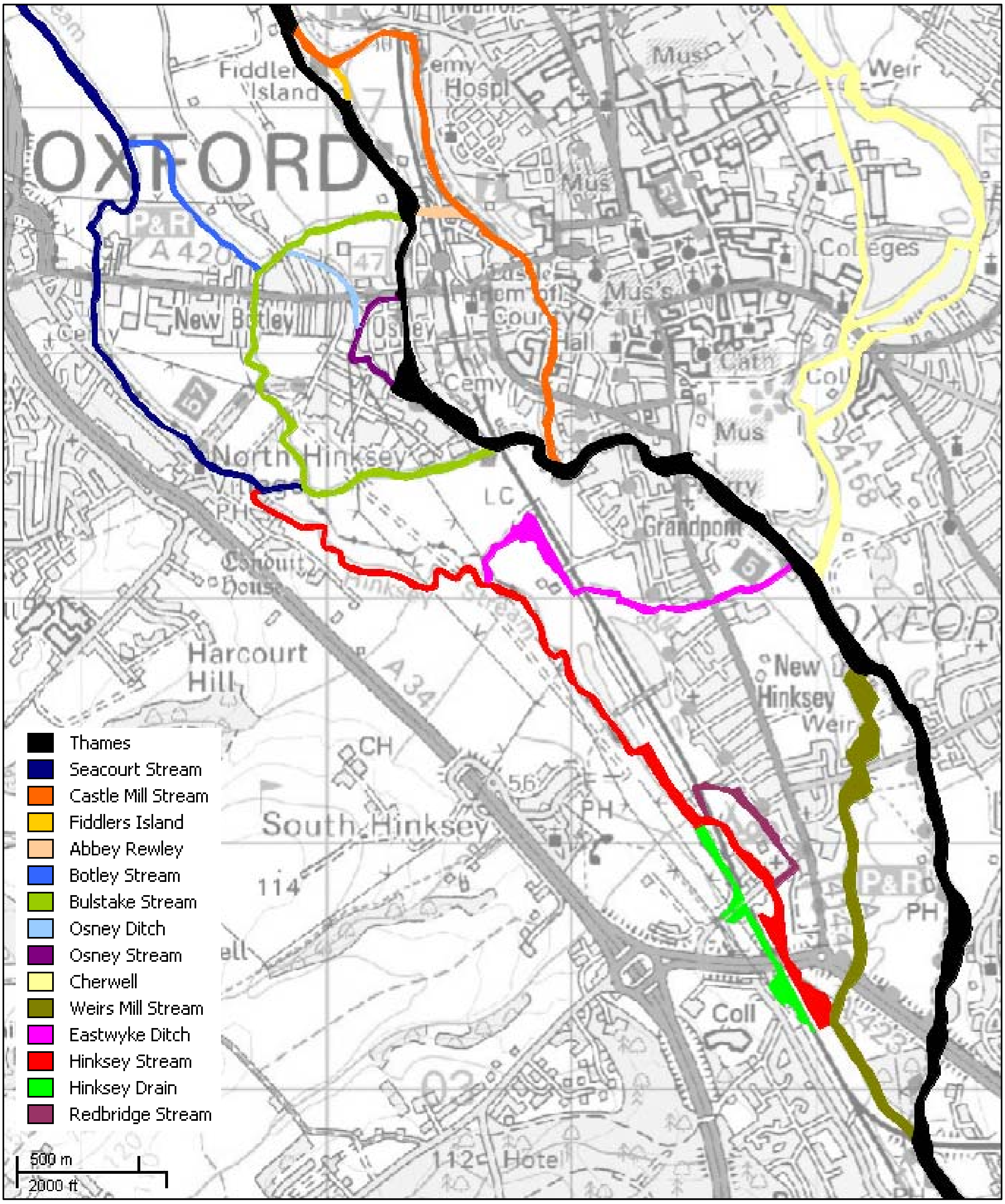

Figure 2: Oxford Rivers and Streams

1.2 Modelling Objectives

The modelling objectives serve to define the purpose of the model. The objectives are:

1. To make full and best use of all existing models and data already available for the study area.
2. To improve confidence in the Mott MacDonald hydraulic model by:
    - implementing recommendations made by B&V in December 2014
    - checking/improving schematisation, especially the western floodplain channels/ditches
    - validating the improved model against the winter 2013/14 flood event
3. To confirm confidence in the JBA hydrological model
4. To develop and utilise a new groundwater model to demonstrate decrease/no increase in groundwater flood risk.
5. To undertake sediment transport modelling
6. To develop high level/conceptual models/reports of surface water flooding and water quality
7. To work with the design team to develop the preferred option, including early analysis of early work planned by Network Rail.

This report covers modelling objectives 1, 2, 3 (full details in hydrology report) and item 7.

1.3 Flood Modeller/TUFLOW

Flood Modeller-TUFLOW combines two software packages for managing overland flow and rapid inundation modelling. It provides a flexible and comprehensive range of tools for designing cost effective engineering schemes, flood forecasting, flood risk mapping and developing catchment management strategies.

Flood Modeller 1D is a 1 dimensional open channel and culverted flow simulation engine, which includes a wide range of hydraulic structures including all common types of bridges, culverts, sluices and weirs. Logical rules are also available which can be added to moveable structures to accurately model how they operate during flood event e.g. automated structures.

TUFLOW is a modelling package for simulating depth averaged 2D free-surface flows, and was developed as a joint research and development project by WBM Oceanics Australia and the University of Queensland.

The project used the following version of Flood Modeller and TUFLOW:

- Flood Modeller Version 4.1.0.159 (calibration), and 4.1.1.160 (design simulations). Both using double precision
- TUFLOW Version 2013-12-AE-iDP-w64. Using double precision

1.4 Report Structure

This report consolidates the technical reports which have be issued during the development of the model through to the outline design. The time line diagram in Figure 3 presents the stages of the modelling and peer reviews.

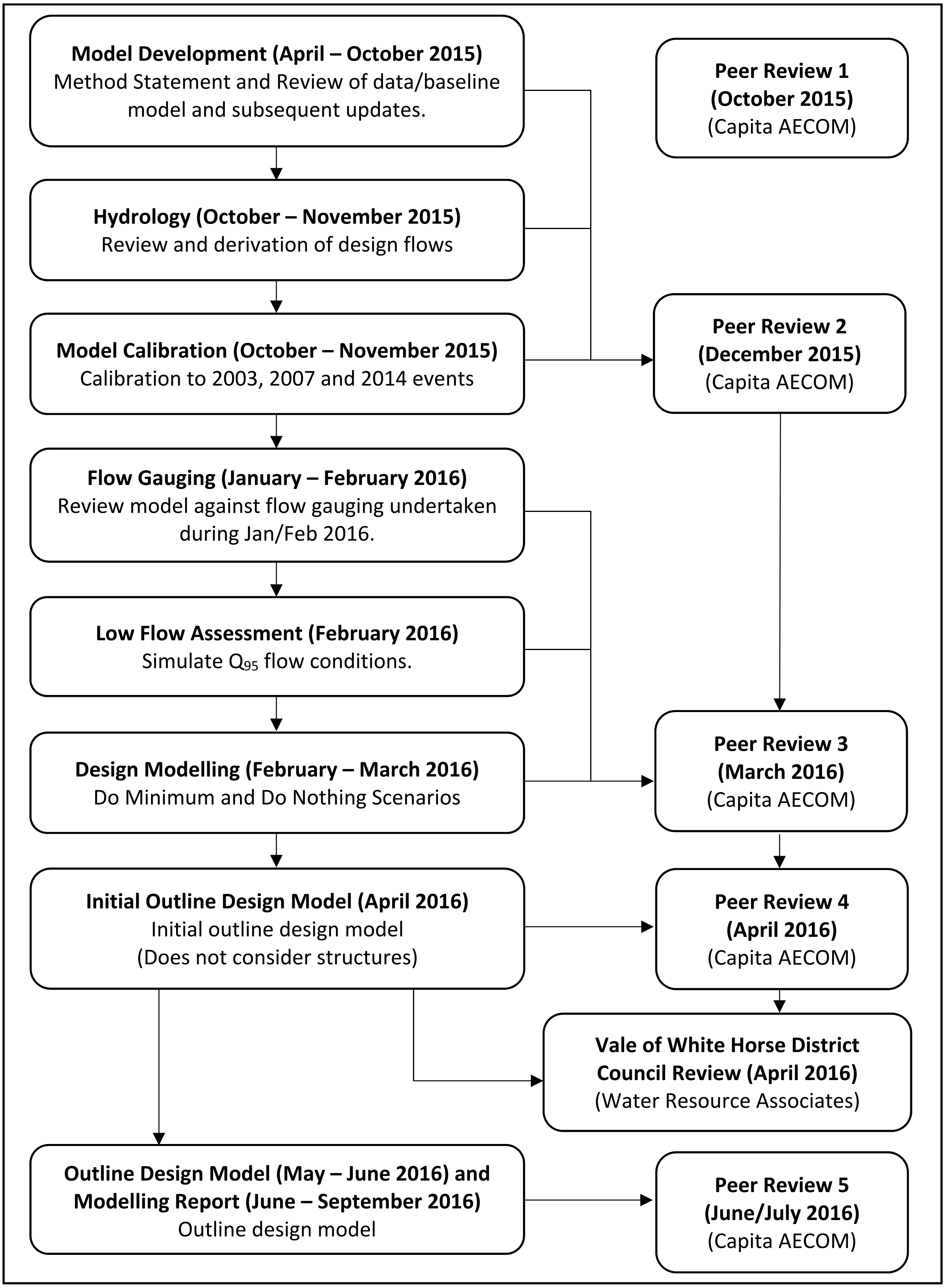

Figure 3: Modelling/study timeline

SECTION 2

Hydrological Assessment

The hydrological assessment includes review of the previous hydrology reports and analysis undertaken to inform the 2009 Oxford Strategy[1] model and the 2014 Oxford Flood Risk Mapping Study[2]. It also records the updates and changes made by CH2M, as part of the modelling for appraisal of the Oxford Flood Alleviation Scheme (FAS). Further detail can be found in the Oxford FAS Final Hydrology Report, February 2016 (IMSE500177-HGL-00-ZZ-RE-N-000077)

To support the modelling for appraisal of Oxford FAS, the assessment determined that local design hydrographs for each of the key tributaries (the River Thames, the River Evenlode, the River Ray and the River Cherwell upstream of its confluence with the Ray) should be developed. Flood frequency analysis at Sandford was updated and extended to include other sites, to increase overall confidence in the design estimates of flow.

The peak flows adopted for the study at Sandford Lock are detailed in Table 1, with comparison to the 2009 Oxford Strategy model and the 2014 Oxford Flood Risk Mapping Study.

Table 1: Peak Flows at Sandford Lock

Return Period (Years)	**Peak Flow (m^3/s)**		
	Oxford FAS	**2009 Strategy (1)**	**2014 Mapping Study (2)**
50% AEP (1 in 2)	140	142	140
20% AEP (1 in 5)	181	183	184
10% AEP (1 in 10)	206	206	-
5% AEP (1 in 20)	231	228	228
3.3% AEP (1 in 30)	246	-	-
2% AEP (1 in 50)	265	257	-
1.3% AEP (1 in 75)	281	268	259
1 % AEP (1 in 100)	292	278	264
0.5% AEP (1 in 200)	320	299	-
0.2% AEP (1 in 500)	359	-	-
0.1 % AEP (1 in 1000)	390	327	299

[1] Black & Veatch, Oxford Flood Risk Management Strategy, Hydrology Report, December 2009 (pub: Environment Agency)

[2] Mott MacDonald, Oxford Flood Risk Mapping Study, January 2014

SECTION 3

Model Development

This section provides a summary of the model development, from the review and updating of the 2014 Mott MacDonald model. Further detail can be found in the Oxford FAS Model Update Report, November 2015 (IMSE500177-HGL-00-ZZ-RE-N-000074).

3.1 Model History

A number of previous hydraulic and hydrological studies have been undertaken. The most relevant studies are summarised below.

Early Models

A number of 1-dimensional (1D) hydraulic modelling studies have been undertaken on the Thames and other rivers through Oxford since at least 1992[3], when PBA produced a series of studies. Between 2002 and 2009, hydraulic modelling was used extensively by Black & Veatch to inform and deliver the Oxford Flood Risk Management Strategy. An interim Black & Veatch model (late 2005) was also used as a starting point for preparation of the Oxford Flood Forecasting model (Edenvale Young, 2007-2009). Black & Veatch subsequently developed a linked 1D-2D flood model of the Oxford area, which was used to support some of the early works which followed the strategy. A copy of the 1D-2D model was not obtained as it is was archived and uses out of data survey data.

Oxford Flood Risk Mapping Model 2014

In 2014, Mott MacDonald and JBA delivered an updated strategic flood risk mapping model for Oxford. The study included a review of the existing hydrology, and development of a linked 1D-2D ISIS-TUFLOW model from just upstream of Kings Lock to downstream of Sandford Lock. The study included calibration and validation of the new 1D-2D model.

Initial Assessment Model

During 2014, the Mott MacDonald model was used by Black and Veatch to support an Initial Assessment (completed in December 2014). As part of this study, Black and Veatch developed the model to schematise the western conveyance scheme (comprising mostly of enlargement of existing channels and new channels). The study concluded with a number of recommendations, which have been addressed as part of the appraisal modelling.

Network Rail Model

In 2015, URS/AECOM further updated the 2014 Mott MacDonald model to improve the representation of rail/road culverts in the Abingdon Road area (modelling culverts in 1D in preference to 2D representation). The model was also used to provide data for sizing of their proposed culvert north of Abingdon Road Bridge.

[3] Black and Veatch (for the Environment Agency), Oxford Flood Risk Management Strategy, 2009, table 3.1.

3.2 Model Updates

Following our detailed review of the Environment Agency's 2014 Strategic Flood Risk Mapping Model, a number of shortcomings were recorded. A summary of some of the issues identified is given as follows:

- Model units did not correctly represent hydraulic controls at some structures. Whilst detailed survey of these structures was available in 2014, it was not used, compromising the accuracy of the model in places (e.g. head of Seacourt Stream, head of Bulstake stream, Town Bridge).
- Some culverts and watercourses were entirely omitted from the 2014 model (e.g. Hagacre Ditch), which reduces confidence in flood levels and flood extents in those areas.
- Some channel sections were oversimplified (represented in 2D) in areas where channel conveyance (and bank levels) are critical (e.g. Eastwyke Ditch and New Hinksey Channel).
- Outdated channel survey was used, where more recent survey was available to the 2014 study, and where differences in bed levels are observed to be significant due to re-profiling works carried out in the past decade (e.g. Osney Ditch).
- Chainage errors were observed, especially on Iffley side weir channel.

The findings of our detailed review led us to make widespread and cumulatively significant changes to the hydraulic model. Large sections of the model were updated with more recent survey data. In total, seven areas were updated, referenced 1 to 7 in Figure 4. The Oxford FAS Model Update Report serves as a record of those changes which also included details to modifications of channel roughness, structure coefficients and model chainages

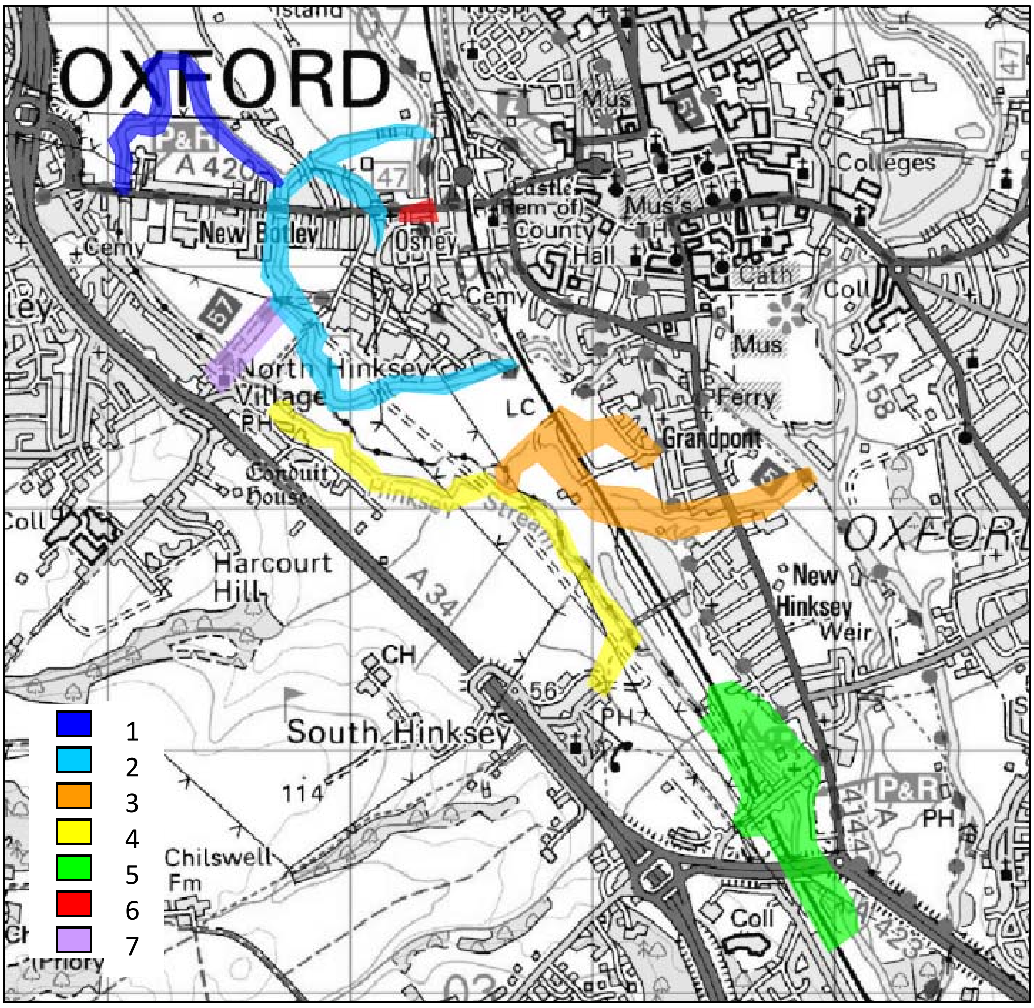

Figure 4: Model update areas

During the model update, care was taken to ensure the model remained stable and ran successfully. Particularly as the updates replaced 2D only channels with linked 1D-2D reaches to provide a more robust and consistent approach to modelling significant watercourses.

During the model update, roughness values and coefficients of approach velocity on structures were compared between previous modelling studies undertaken by Mott MacDonald and Black & Veatch. The values adopted in the updated model generally sit between these values

3.3 Representation of Buildings

Buildings in the 2D domain of the flood mapping model were previously represented using the 'stubby building' method, where the building footprint is raised by 0.30m. To enable the model outputs to be used for economic analysis we have removed this building adjustment layer and increased the 2D roughness for buildings to a value of 1.0.

Given the 2D cell size for the model (10m), the removal of the 'stubby building' is appropriate to ensure flow paths are not blocked by the 0.30m increase in levels of the building footprint.

The property dataset includes an extensive amount of surveyed threshold data, which is used for the economic analysis. Where threshold data is not available the DTM level + 0.15m is taken as the threshold level.

3.4 Bathymetric Survey

The model cross sections covering a 2km reach of the Thames in the Osney Reach were compared to a channel survey from 2014 (survey ref. 12512) and Bathymetric Survey from 2015 (survey ref. 12589). The comparison indicates a reasonable match with the survey data used in the model. As detailed in Figure 5, the date of survey sections within the model are unknown but are thought to date from the early 1980's).

The River Thames Bathymetric Data Analysis Study (EA, January 2016)[4] has reviewed and compared bathymetric surveys of the Thames, to determine if there have been significant changes in bathymetry since wide scale dredging of the river ceased in 1998. The reaches in the study area indicate that average bed levels have increased upstream of Osney and reduced downstream. However, it is noted that it is not possible to determine whether the net rise in level in the last 9 years is part of a longer term trend in increasing level. For some of these reaches the change in level is within the range of uncertainty in the original survey data. Table 2 details the net change in average bed level for the reaches in the study area.

Based on the survey check and bathymetric data analysis study, it was concluded that updating the model sections using bathymetric survey was not required. However, it is recognised that the bed of the Thames is mobile and this will be explored as a sensitivity test on the outline design of the scheme.

[4] CH2M (for the Environment Agency), River Thames Bathymetric Data Analysis Study, 2016

Table 2: Bathymetry – net change in average bed levels

Reach	Surveys		Total Period of Record (years)	Net change in average bed level over period of record (m)	Total number of surveys for reach	Range of changes in average bed level over period of record (m)	
	Earliest	Latest				Maximum	Minimum
King's	2006	2015	9	+0.06	2	+0.06	*
Godstow	2006	2015	9	**+0.11**	2	**+0.11**	*
Osney	2006	2015	9	+0.10	2	+0.10	*
Iffley	2004	2015	11	**-0.13**	2	*	**-0.13**
Sandford	2004	2015	11	-0.06	2	*	-0.06
Abingdon	2004	2015	11	**-0.14**	2	*	**-0.14**

(shaded)	Indicates increase in average bed level
*	Indicates only two surveys available – single calculation of change
BOLD	Indicate results greater than data uncertainty range

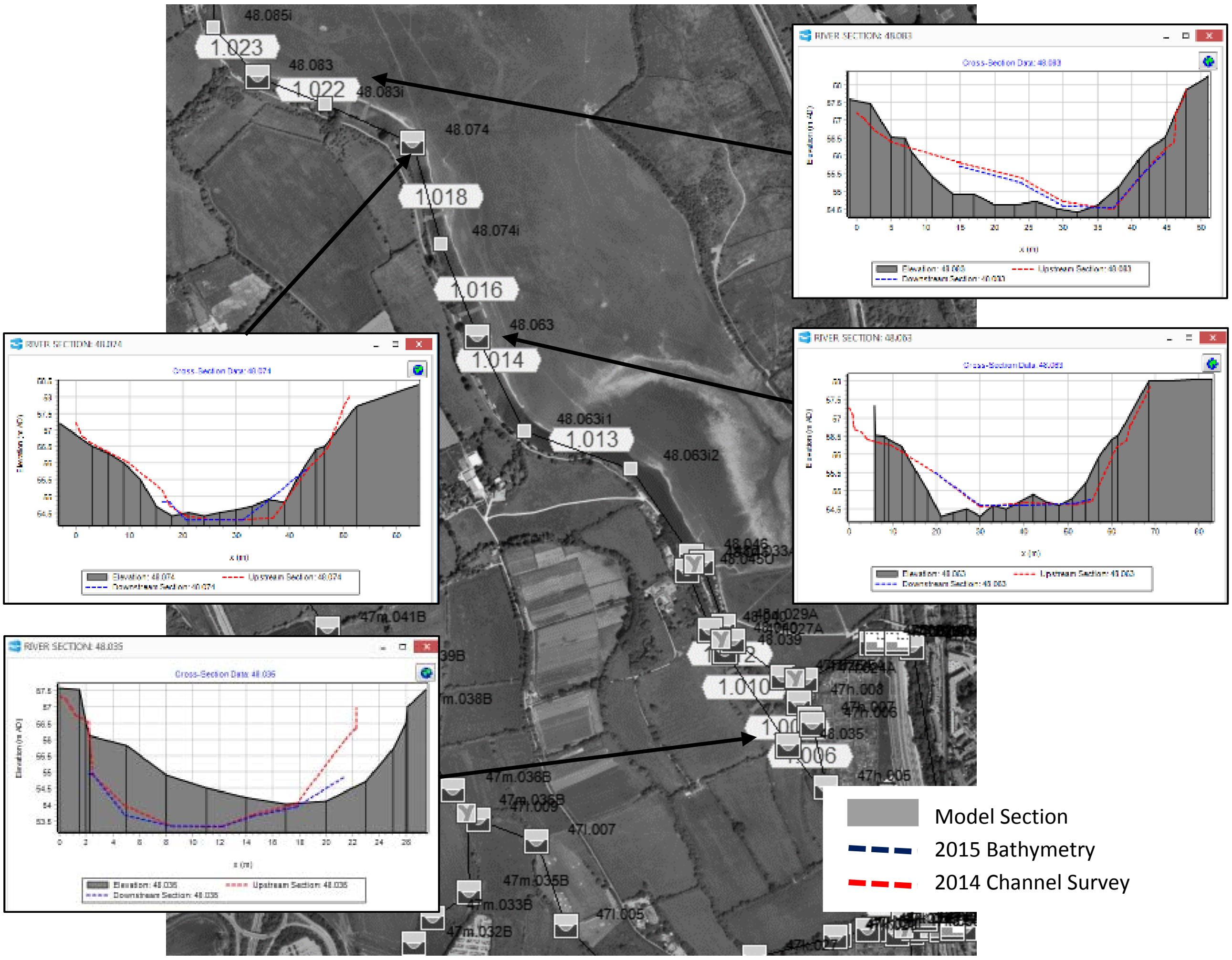

Figure 5: Comparison of model sections to 2014 survey and 2015 bathymetry
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SECTION 4

Model Calibration

Calibration and validation modelling was undertaken to improve confidence in the model outputs using the model updated for the Oxford FAS study (refer to Section 3 for details of model development). The following calibration and validation modelling was undertaken:

1. Re-calibration of the July 2007 event, following the recommendations made by Black and Veatch Limited (B&V) when using the Mott MacDonald model for Initial Assessment modelling in December 2014.
2. Validation of the re-calibrated model to the winter 2013/14 flood event.
3. Additional validation using the 2003 flood event.

This section provides a summary to the calibration process and results, further detail can be found in the Oxford FAS Final Calibration Report, June 2016 (IMSE500177-HGL-00-ZZ-RE-N-000075).

4.1 Summary of calibration input data

The input data used for calibration (models and inflows) was as follows:

- The same 1D model (Oxford_CH2M_R.DAT) was used for all calibration events, with inflows and gate operations controlled with IED files.
- The same 2D model components were used for the 2003 and 2007 events.
- The winter 2013/14 event includes additional 2D model files to represent the 3 culverts under Willow Walk (installed since 2007) and the temporary defences which were deployed at Osney Island and Hinksey Park.
- Inflows were derived at 3 main inflow locations using outputs from the Oxford Flood Forecasting model (2009), gauge records and the current high-flow ratings. The main inflow locations are:
    1. River Thames upstream of Evenlode confluence (u/s gauge 39008 Eynsham and Farmoor)
    2. Evenlode at Thames confluence (gauge ref 39034 Cassington)
    3. Cherwell at A40 (upstream gauges 39021 Cherwell @ Enslow and 39140 Ray @ Islip)
- The calibration events for 2007 and 2003 events were simulated for the Oxford Flood Forecasting model study (2009) and are considered to be the best estimate of flow for those events. The latest flood forecasting model "OxfordThames_41.dat" was used to extract flows from model nodes 50.079 (Thames), 50.EVEN (Evenlode) and CH.082d (Cherwell).
- The flood forecasting model did not have stored results for the 2013/14 event, so inflows were derived from gauge records and high flow ratings. The flood forecasting model was then used to simulate the derived flows and extract inflows for the 1D-2D model nodes.
- The model inflows for each event and flow at Sandford (extracted from the 1D-2D simulation) are detailed in Figure 6 (2007), Figure 7 (2013/14) and Figure 8 (2003). Flows based on lock keeper tackle sheets and telemetry (2013/14 event only) are included using the tail rating at Sandford. The Sandford Tail Water Level rating developed by Black & Veatch, in Oxford Flood Risk Management Strategy, Hydrology Report, 2009 was used. Note that at high flows water levels exceed the top of the gauge board and are not recorded in the tackle sheets
- Sandford Tail Rating (Datum = 48.80mAOD)

  $Q = 2.661\, h^{2.659}$ for $h<4.55$

  $Q = 0.815\, h^{3.441}$ for $h>4.55$

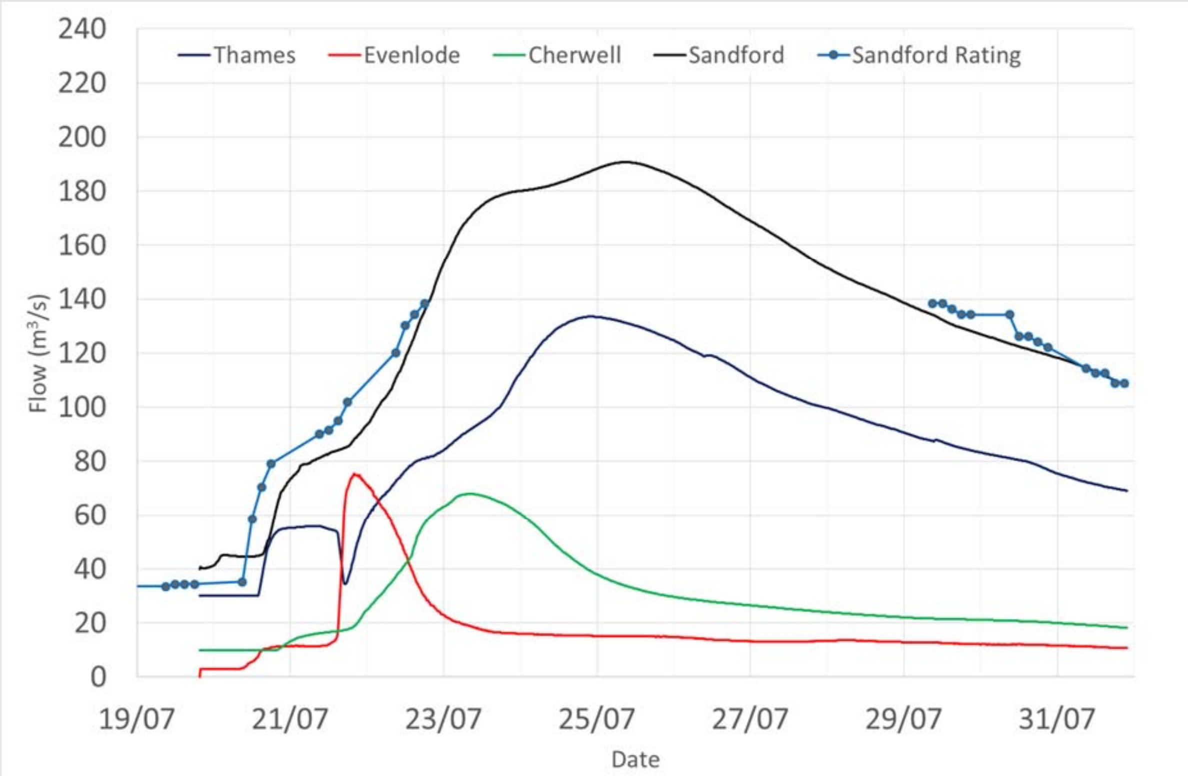


Figure 6: Calibration inflows and Sandford flow – 2007 event

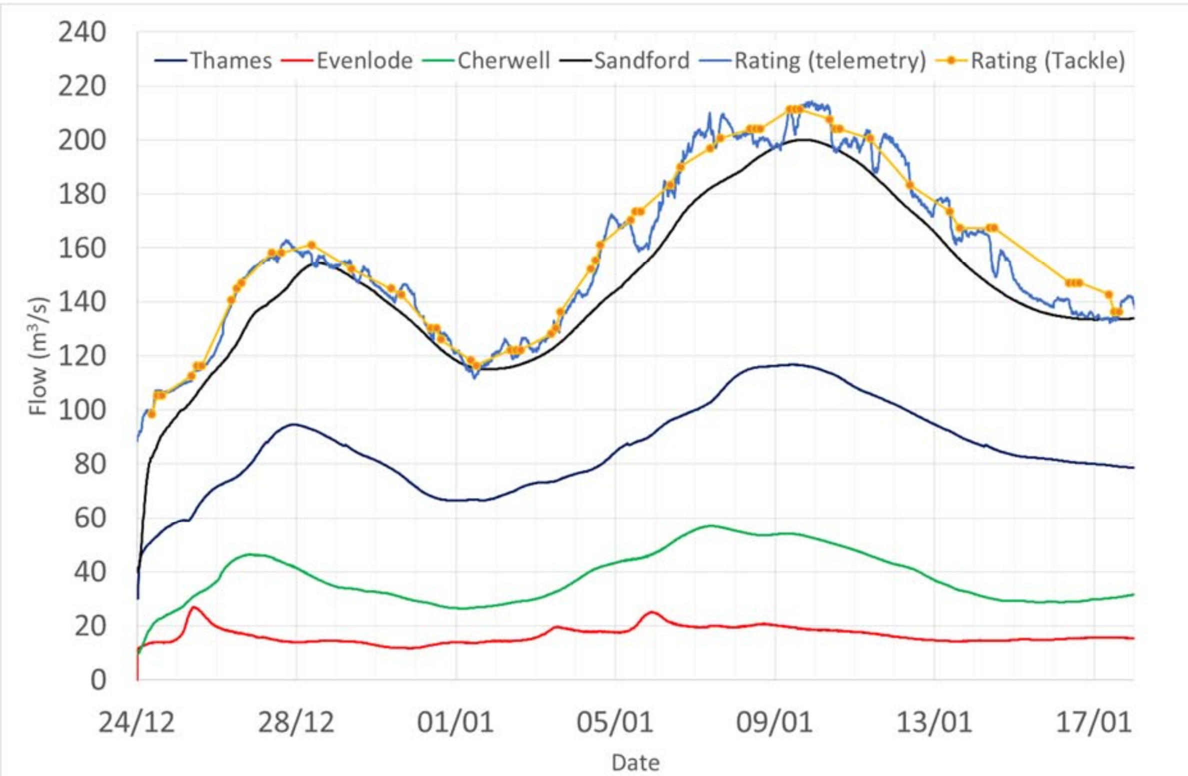


Figure 7: Calibration inflows and Sandford flow – 2013/14 event

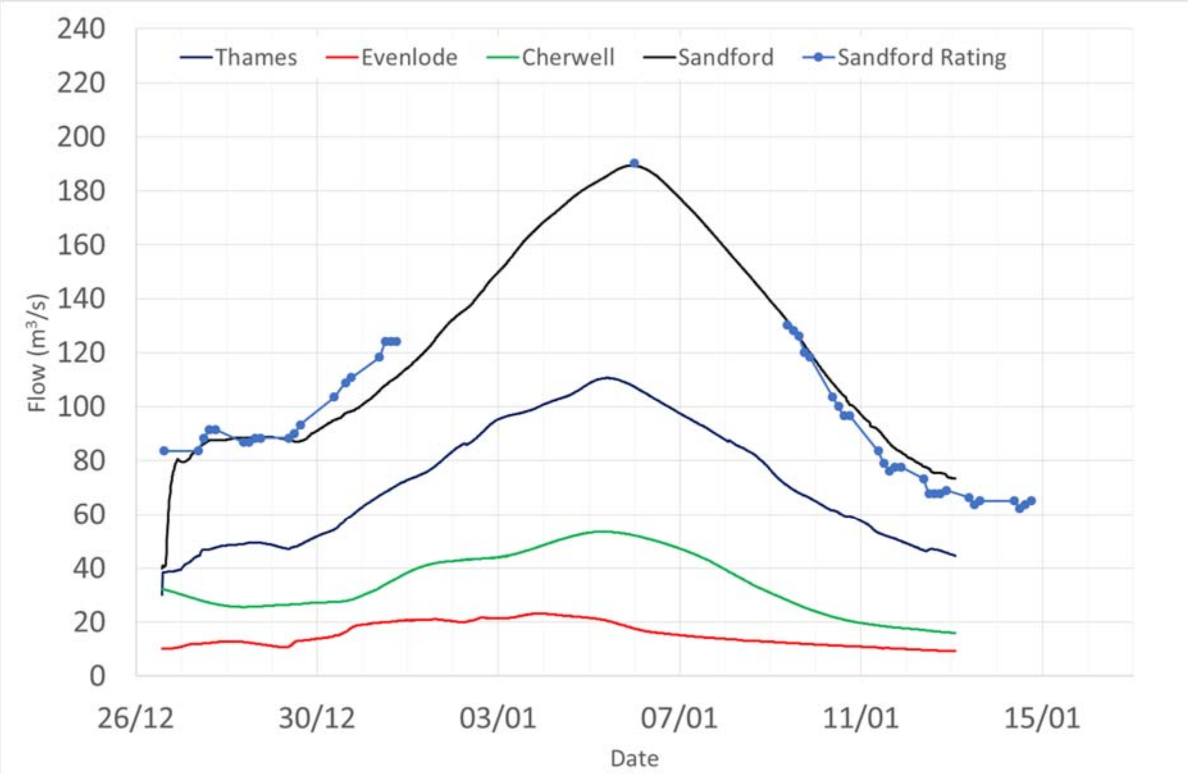


Figure 8: Calibration inflows and Sandford flow – 2003 event

4.2 Summary of calibration results

Comparison of model performance against the observed data was made against various datasets for the 2007 event:

- Telemetry data at locks (head and tail), recorders on Botley Road on the Seacourt Stream (Minns Estate), Bulstake Stream (New Botley), Abingdon Road on Hinksey Stream (Cold Harbour) and Oxford gauge on the Cherwell.
- Flood Extent comparison.
- Post flood survey at 38 locations, based on wrack marks and photographic evidence of flood extents.

The results are summarised below for each event, based on the peak water levels from telemetry data. The calibration report includes further comparison of the model outputs to records including flood extents, post flood surveys and time series comparison to the telemetry data.

- For 2007, comparison of the observed peak water levels from the telemetry stations to modelled water levels (Table 3). Generally there is good agreement with all peak levels within 0.13m apart from the comparisons at Sandford Lock (head and tail), where telemetry data was not available and water levels exceed the top of the gauge board for high flows. Here, comparisons are made against the observed levels presented in the Oxford Initial Assessment Report (the source of water levels are unknown).
- For 2013/14, generally there is good agreement with all peak levels within 0.15m (Table 4), apart from at the Oxford Gauge on the Cherwell. This is likely to be due to missing flows from the Ray (discussed in calibration report). The impacts of a missing flow could also cause the lower than observed levels at the Locks downstream of Osney.
- For 2003, there is good agreement with all peak levels within 0.13m (Table 5).

Table 3: Comparison of observed and modelled water levels – July 2007

Location (model node)	Observed Level (mAOD)	Modelled Level (mAOD)	Difference (m)
Kings Lock Head (50.008)	59.58	59.47	-0.11
Kings Lock Tail (49.050)	59.22	59.11	-0.11
Godstow Lock Head (49.003U)	58.31	58.25	-0.06
Godstow Lock Tail (48.085)	57.99	57.87	-0.12
Osney Lock Head (48.HRU)	56.80	56.75	-0.04
Osney Lock Tail (47.125)	56.40	56.33	-0.07
Iffley Lock Head (TH47_003)	55.40	55.32	-0.08
Iffley Lock Tail (46.052)	54.99	55.01	0.02
Sandford Lock Head (46c_002A)	54.49 (1)	54.33	-0.16
Sandford Lock Tail (45.164)	53.97 (1)	53.67	-0.30
Minns Estate (47m.26B)	57.12	57.01	-0.11
New Botley (47k.017)	57.14	57.06	-0.08
Cold Harbour (46g.012C)	55.69	55.81	0.12
Ice Rink (47f.103F)	56.24 (1)	56.11	-0.13
Cherwell (CH.014)	56.00	56.05	0.05

Source (1): Oxford Initial Assessment Modelling Report, December 2014, Table 6.3. (The source of the observed water levels are unknown, telemetry data was not available at Sandford for 2007 and the water levels exceed the top of the gauge boards).

Table 4: Comparison of observed and modelled water levels – Winter 2013/14

Location (model node)	Observed Level (mAOD)	Modelled Level (mAOD)	Difference (m)
Kings Lock Head (50.008)	59.47	59.45	-0.02
Kings Lock Tail (49.050)	59.08	59.08	0.01
Godstow Lock Head (49.003U)	58.23	58.22	-0.02
Godstow Lock Tail (48.085)	57.90	57.84	-0.06
Osney Lock Head (48.HRU)	56.70	56.70	0.00
Osney Lock Tail (47.125)	56.45	56.30	-0.15
Iffley Lock Head (TH47_003)	55.47	55.39	-0.08
Iffley Lock Tail (46.052)	55.18	55.06	-0.12
Sandford Lock Head (46c_002A)	54.49	54.35	-0.13
Sandford Lock Tail (45.164)	53.85	53.72	-0.13
Minns Estate (47m.26B)	57.09	56.96	-0.13
New Botley (47k.017)	57.03	57.00	-0.04
Cold Harbour (46g.012C)	55.70	55.77	0.07
Ice Rink (47f.103F)	n/a	56.11	n/a
Cherwell (CH.014)	56.32	56.00	-0.33

Table 5: Comparison of observed and modelled water levels – January 2003

Location (model node)	Observed Level (mAOD)	Modelled Level (mAOD)	Difference (m)
Kings Lock Head (50.008)	59.42	59.44	0.01
Kings Lock Tail (49.050)	59.13	59.07	-0.05
Godstow Lock Head (49.003U)	58.30	58.20	-0.09
Godstow Lock Tail (48.085)	57.95	57.82	-0.13
Osney Lock Head (48.HRU)	56.71	56.67	-0.05
Osney Lock Tail (47.125)	56.38	56.26	-0.12
Iffley Lock Head (TH47_003)	55.42	55.33	-0.09
Iffley Lock Tail (46.052)	55.09	55.01	-0.09
Sandford Lock Head (46c_002A)	54.39 (1)	54.32	-0.07
Sandford Lock Tail (45.164)	53.68 (2)	53.66	-0.02
Minns Estate (47m.26B)	n/a	56.94	n/a
New Botley (47k.017)	56.92	56.97	0.04
Cold Harbour (46g.012C)	55.74	55.67	-0.07
Ice Rink (47f.103F)	n/a	56.06	n/a
Cherwell (CH.014)	n/a	55.97	n/a

Source (1): OFRMS Hydraulic Modelling Report, 2009, Table 4.4

Source (2): 2002/3 Flood levels Sandford Lock level survey, Survey 8515, 27 October 2005

4.3 Conclusions drawn from the model calibration

The calibration and validation work undertaken by CH2M has greatly improved the performance of the model when compared with observed events, particularly for the 2007 flood. The successful validation of the re-calibration of the model against the 2003 event and the most recent 2013/14 event provides further confidence in the model's schematisation and baseline parameter settings. The model's improved performance is a result of the following changes implemented by CH2M:

- Improved model inflows, with special care being taken to review and reconstruct appropriate inflows for each calibration and validation event;
- Improved model parameters (for example, channel roughness);
- Improved model schematisation (for example, by incorporating more recent survey).

Given the successful outcome of the re-calibration and validation exercise, the calibrated model is now considered to be suitable for supporting the development of options and their outline design.

Flow Gauging

5.1 Overview

The Environment Agency are currently undertaking a programme of spot flow gauging at 7 locations in Oxford to improve the understanding of how the flows split though the various channels, particularly around Botley Road. The locations of the gauge sites are detailed in Figure 9 and Table 6. Gauging's have been taken on the 12th, 28th January 2016 and the 11th February 2016.

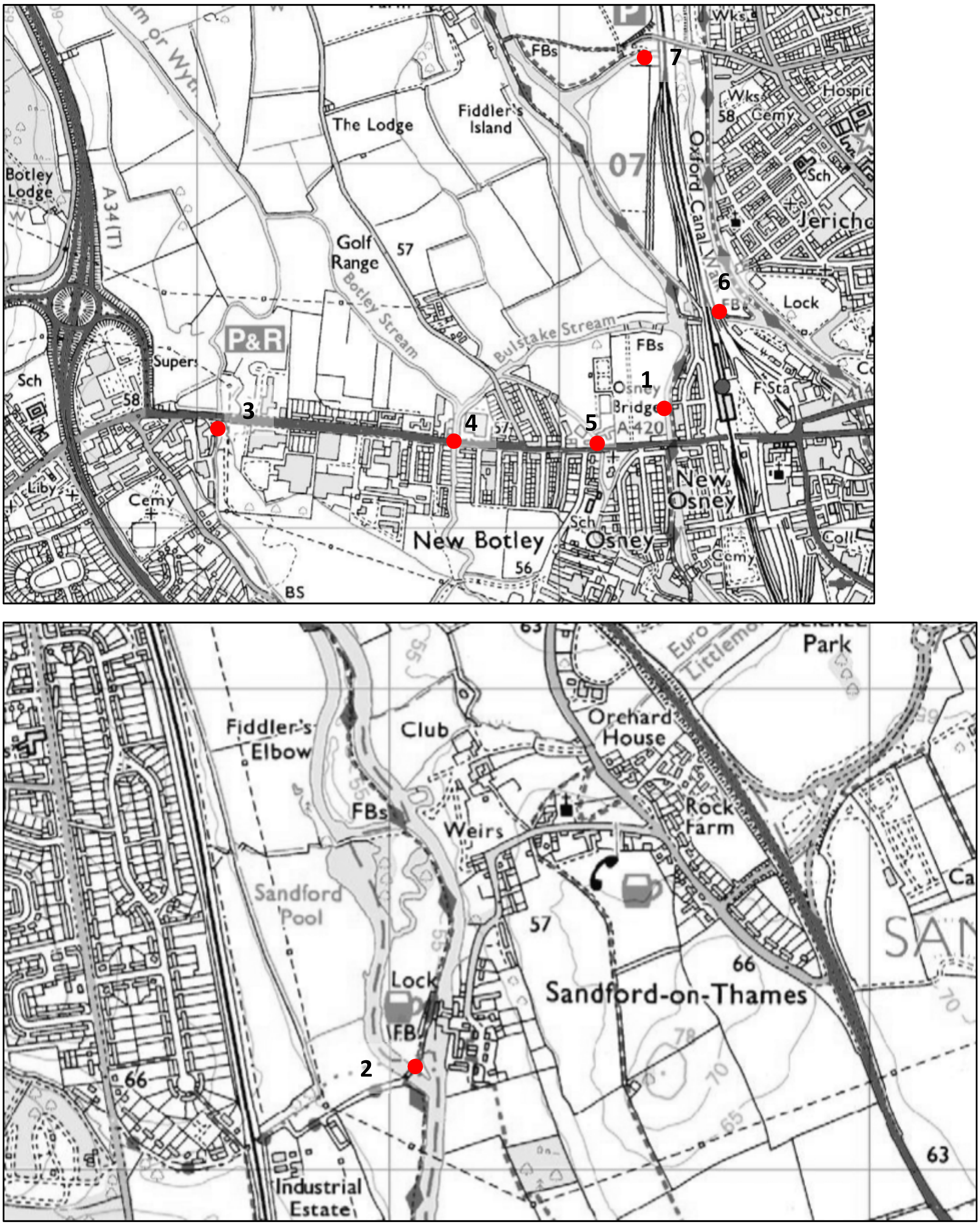
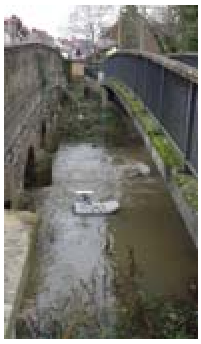


Figure 9: Flow gauging locations

Table 6: Flow gauging locations

Ref	Location	Description	Photograph
1	Thames (Osney)	Thames at Botley road, 65m u/s Osney Bridge	
2	Thames (Sandford)	R Thames at Sandford, DS bridge	
3	Seacourt Stream	At flood warning station	No photo
4	Bulstake Stream	Downstream face of Botley road bridge	
5	Osney Ditch	Downstream face of upstream footbridge	
6	Rewley Bridge	At Bridge	
7	Castle mill stream	Cripley Halls Bridge, Port meadow	

5.2 Flow gauging input data

The flood modeller 1D hydraulic model, used for calibration with minor updates based on the peer review has been used to compare the flows gauged to model flows. The flow gaugings on the 12th, 28th January 2016 and the 11th February 2016 are considered as ‘in bank’, particularly at Botley Road, although some out of bank flooding would occur off King’s Weir. Therefore, the 2D TUFLOW component of the model was not required. If future gauging’s are undertaken during out of bank flood conditions then use of the combined 1D-2D model will be considered.

The model has been run with constant flow, based on the recorded flows from gauging stations at Farmoor (Thames), Cassington (Evenlode), Enslow (Cherwell) and Islip (Ray). The recorded flows have been taken from the website http://oxfloodalliance.org.uk/river-gauges/. Where necessary, the following high flow ratings detailed in Figure 10 have been used to convert recorded water levels to flows.

Farmoor — For flows > 50m^3/s

$Q=55.234*(h+0)^{0.7803}$ for $h < 1.33$
$Q=48.364*(h+0)^{1.2460}$ for $h < 1.55$
$Q=37.886*(h+0)^{1.8032}$ for $h < 1.76$
$Q=23.541*(h+0)^{2.6449}$ for $h < 1.93$
$Q=3.1432*(h+0)^{5.7072}$ for $h > 2.2$

Cassington (Evenlode)

$Q=20.586*(h+0)^{1.879}$ for $h < 0.67$
$Q=21.665*(h+0)^{2.0066}$ for $h < 0.874$
$Q=27.526*(h+0)^{3.7843}$ for $h < 0.98$
$Q=27.604*(h+0)^{3.9252}$ for $h > 0.98$

Enslow (head rating)

$Q=17.857*(h+0)^{1.7668}$ for $h<0.71$
$Q=29.465*(h+0)^{3.2291}$ for $h<0.88$
$Q=37.096*(h+0)^{5.0307}$ for $h<1.01$
$Q=38.437*(h+0)^{1.4625}$ for $h>1.01$

Source: EdenVale Modelling Services (2007) Hydraulic models for Flood Forecasting: Oxford Thames

Figure 10: High flow ratings

Based on the records at gauging stations, Table 7 details the constant inflows run though the model on the day of the spot flow gauging.

Table 7: Flow gauging inflows

Ref	12 Jan 16 @10:00	28 Jan 16 @10:00	11 Feb 16 @12:00
Farmoor	73.3	37.7	78.9
Cassington	11.3	5.5	10.1
Total Thames	**84.6**	**43.2**	**89.0**
Enslow	17.0	6.5	18.1
Islip	10.0	7.0 (1)	5.0 (1)
Total Cherwell	**27.0**	**13.5**	**23.1**
Total Inflow	**111.6**	**56.5**	**112.1**

(1) Islip Gauging station not operational, flow assumed to match gauged flow at Sandford

5.3 Update to model based on flow gauging

The initial model output for the spot flows taken on the 12th January, over predicted the flow at site 7 (Cripley Halls Bridge) with modelled estimate of 13.26m^3/s compared to gauged flow of 7.17m^3/s and at site 6 (Rewley Bridge) suggested the channel was flowing in the wrong direction (modelled estimate of -0.62m^3/s compared to gauged flow of 5.09m^3/s).

The model cross sections were checked in the Castle Mill Stream reach against survey from 1988 (survey ref 00967), which showed the model cross sections had lower bed levels than the survey sections (approximately 1m lower, see Figure 11 below). The model sections were updated and the roughness was locally increased to 0.080 due to the limited coverage of sections in the reach (sections only at bridges). The model updates reduced the flow at site 7 to improve the comparison to the spot flow and corrected the flow direction at site 6. The updates have been incorporated back into the model used for the Oxford FAS study.

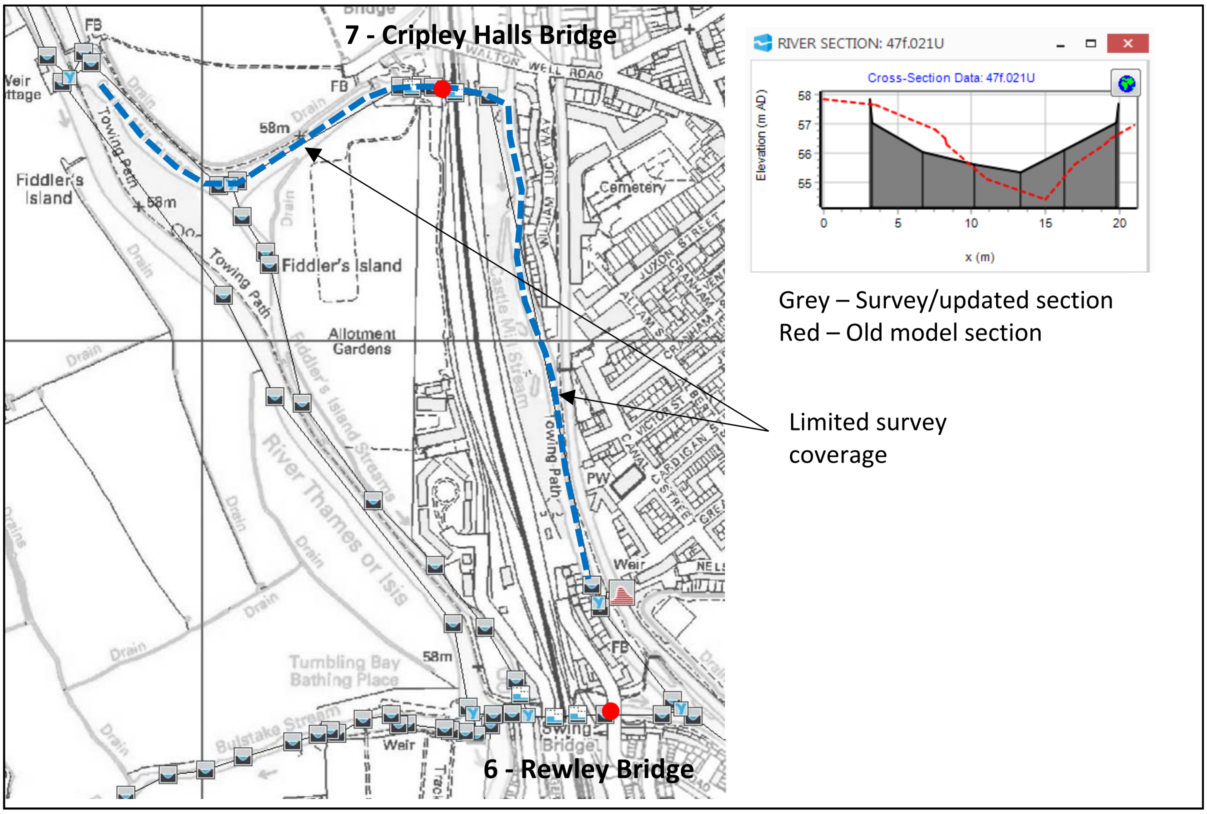


Figure 11: Castle Mill Stream

5.4 Flow gauging results

Comparisons of the gauged spot flows to modelled flows are detailed in Table 8 (12Th Jan), Table 9 (28th Jan) and Table 10 (11th Feb). Overall there is good agreement with the flow splits through Botley Road

It may be possible to further improve the results if the model is run with varying flows from the gauging stations (instead of a constant flow) and actual gate openings used at structures, particularly at Kings Weir, Osney Lock and Castle Mill Weir which influence the flow splits.

Nonetheless, the results are very promising and build further confidence in the schematisation of the model, and the division of flow between the various channels. Having this confidence allowed continuation to the next stage of the study; the outline design of the preferred option.

Table 8: Flow Gauging 12th January 2016

Ref	Location	Date	Recorded Stage (mAOD)	Gauged Flow (m^3/s)	Model Stage (mAOD)	Model Flow (m^3/s)	Stage Diff (m)	Flow Diff (m^3/s)
1	Thames (Osney)	12/01/2016 13:50	56.49	45.48	56.59	48.75	0.10	3.27
2	Thames (Sandford)	12/01/2016 10:25	52.82	111.86	53.03	111.62	0.21	-0.24
3	Seacourt Stream	12/01/2016 11:19	56.29	4.35	56.38	4.86	0.09	0.51
4	Bulstake Stream	12/01/2016 12:03	56.46	16.00	56.46	16.02	0.00	0.02
5	Osney Ditch	12/01/2016 13:03	-	3.01	56.11	2.60	n/a	-0.41
6	Rewley Bridge	12/01/2016 14:34	-	5.09	57.13	4.90	n/a	-0.19
7	Castle mill stream	12/01/2016 15:21	57.38	7.17	57.38	7.48	0.00	0.31

Table 9: Flow Gauging 28th January 2016

Ref	Location	Date	Recorded Stage (mAOD)	Gauged Flow (m^3/s)	Model Stage (mAOD)	Model Flow (m^3/s)	Stage Diff (m)	Flow Diff (m^3/s)
1	Thames (Osney)	28/01/2016 12:31	56.55	30.96	56.43	28.84	-0.12	-2.12
2	Thames (Sandford)	28/01/2016 09:58	51.92	56.7	52.13	57.25	0.21	0.55
3	Seacourt Stream	28/01/2016 10:41	55.45	1.32	55.51	1.12	0.06	-0.20
4	Bulstake Stream	28/01/2016 11:03	55.53	4.73	55.47	4.6	-0.06	-0.13
5	Osney Ditch	28/01/2016 12:01	-	0.56	55.31	0.25	n/a	-0.31
6	Rewley Bridge	28/01/2016 13:03	-	5.33	56.73	5.06	n/a	-0.27
7	Castle mill stream	28/01/2016 13:35	57.01	4.77	56.87	3.33	-0.14	-1.44

Table 10: Flow Gauging 11th February 2016

Ref	Location	Date	Recorded Stage (mAOD)	Gauged Flow (m^3/s)	Model Stage (mAOD)	Model Flow (m^3/s)	Stage Diff (m)	Flow Diff (m^3/s)
1	Thames (Osney)	11/02/2016 14:04	56.52	45.35	56.63	50.43	0.11	5.08
2	Thames (Sandford)	11/02/2016 17:35	53.08	111.62	53.03	112.12	-0.05	0.50
3	Seacourt Stream	11/02/2016	56.44	7.19	56.46	5.45	0.02	-1.74
4	Bulstake Stream	11/02/2016	56.54	19.6	56.55	17.25	0.01	-2.35
5	Osney Ditch	11/02/2016	-	5.86	56.17	3.08	n/a	-2.78
6	Rewley Bridge	11/02/2016	-	4.73	57.17	4.88	n/a	0.15
7	Castle mill stream	11/02/2016	57.4	8.89	57.43	7.91	0.03	-0.98

SECTION 6

Design Simulations and Results

Following the model calibration, subsequent model review (Peer Review 2) and recent spot flow gauging, the model has been further updated. This section summarises the model updates and assumptions/outputs for the 'Do Minimum' and 'Do Nothing' scenarios.

6.1 Sensitivity tests following Peer Review 2

As recommended in the Oxford FAS Peer 2 model review, sensitivity tests for the model parameters, detailed in Table 11, have been undertaken using draft 100 year event flows. Model results are presented in Appendix A at the locations reported in the model calibration report (telemetry locations).

Table 11: Peer 2 review sensitivity tests - model parameters tested

Test	Parameter/description	Value Tested
1	2D HX line FLC (ii) Assigning a FLC (typically 0.1 to 0.5 in value) to HX lines using the 2d_bc "a" attribute. For HX lines running along the river banks, especially those with high overtopping velocities, improved stability and representation of the energy lost as the water peels off from the river to floodplain or vica versa can be realised.	0.5
2a	2D Boundary Viscosity Factor (includes HX line FLC adjustment) **New .tcf command "Boundary Viscosity Factor =="** multiplies the eddy viscosity coefficient by the factor along all open (external) boundaries and 2D / HX links. For these boundaries the eddy viscosity coefficient was previously set to zero for the boundary cells (this is because land boundaries require this). The default factor is kept at zero for backward compatibility, except for **"Link 2D2D Approach == METHOD D" the default is set to 1.0**, ie. the standard eddy viscosity coefficient is applied as this can provide an improved performance in flow patterns along the 2D link lines. Changing this value in the range of 0.0 to 5.0 (possibly higher) usually has little effect on results, however, increasing the factor can help "stabilise" unrealistic circulations along a boundary or 2D / HX link line without adversely affecting results. As with all new features, sensitivity test prior to adopting, especially for larger factors. Setting this value to 1.0 as the default and being able to vary this value for different boundaries/links will be considered for the TUFLOW 2014 release, so please send any feedback, good or bad, to support@tuflow.com.	1
2b		3
3	Downstream boundary Model downstream boundary represented within the 1D model as a normal depth boundary.	+0.25m

The sensitivity tests predict a small increase in peak water level of 1cm for test 1 (form loss in HX line), when including the 2D boundary viscosity factors of 1 or 3 (tests 2a and 2b) the increases are 1cm – 2cm. Including these adjustments slows flow from the 1D to 2D domain, which is shown in the peak model outflow which increases for each test (flow increase of 2.40m3/s for test 2b). The adjustments have been found to reduce oscillations between the 1D-2D domains (see Appendix A).

Due to the minor impact in water levels/flows and stability benefits between 1D and 2D the HX FLC value of 0.5 and Boundary Viscosity Factor of 3 will be used for all future simulations on the Oxford FAS study.

The sensitivity tests on the downstream boundary show that the impact on water levels extends just upstream of Sandford lock (increase in 1cm), there is no increase in water level at Iffley Lock (Head and Tail)

6.2 Summary of model updates

Table 12 details the model updates to develop the 'Do Minimum' model. This represents the current conditions (year 2015), and perhaps most importantly, omits the future works proposed by Network Rail, which at the time of developing this model, were out to consultation. The previous calibration 1D model (Oxford_CH2M_R.DAT) and associated 2D schematisation was used as the base model to which the updates were applied.

Table 12: Record of model Update

Ref	Details of update	Data Source or survey
1	Cross section panel markers checked and updated where necessary to remove any sections with decreasing conveyance (within flood modeller DAT file)	Peer Review 2 and response
2	Potential flow route identified under A34 new Wytham (NGR 448090, 208625), added to 2D domain (2d_lfcsh_culverts_Oxford_F_polyline.shp)	Peer Review 2 and response
3	Bridge units updated orifice flow when surcharged (within flood modeller DAT file)	Peer Review 2 and response
4	Form loss of 0.5 added to all 2D HX lines 'a' attribute (2d_bc_hx_Oxford_HXFLC.shp)	Peer Review 2 and response
5	2D Boundary Viscosity Factor added to all model simulations (value of 3, added to TCF files)	Peer Review 2 and response
6	Model updated to represent tilting gate and fish pass at Osney, dimensions estimated from survey GA. Tilting gate (node 48.TU) 5.4m wide, gate height of 2.5m with crest level of 54.08mAOD. Fish Pass (node 48.FU) 1.6m wide, with crest level of 56.45mAOD. Hydro power station not modelled	Surveys 096.10, 096.11 and BH_104
7	Mundays Bridge and sections (model nodes MU01.009 to MU01.001) updated using Thames Water cross sections, which represent some clearing of the channel, removal of the weir and wall on right bank	Surveys B174-A3-23905 and B174-A3-00606
8	Castle Mill Stream cross sections (model nodes 47f.024A to 47f.011U) changed based on survey 00967, following model checks against spot flow gauging during Jan/Feb 2016	Flow Gauging Survey 00967

Most of the changes above are deemed relatively minor and/or localised, and do not require the model to be re-calibrated. The most significant change is the clearance through Mundays Bridge, but it is believed that this was undertaken after the 2013/14 flood event (the most recent event used in our calibration and validation of the model).

6.2.1 South Hinksey Temporary Flood Barriers

Details of the South Hinksey temporary flood barrier alignment were received after completion of the Do Minimum design simulations. The alignment has been checked and follows the defence line used within the model.

6.2.2 Maximum Gate Openings

The model includes assumptions for maximum gate openings. Table 13 lists the maximum openings with the peak 100 year water level for the Do Minimum scenario. Comparison of the maximum opening and peak water level shows that all gates are clear of the 100 year water surface apart from Iffley Weir B. It has since been confirmed by the EA that the bottom of Iffley Buck gate would be somewhere near to 54.5m AOD, which is lower than it might appear on the weir drawings, because the gate has stiffening plates that would catch on the underside of the walkway preventing it from being raised further. There is an ongoing EA study to modify the gate to allow it to be raised clear.

Table 13: Maximum Gate Openings assumed in the model

Structure Name	Node	Type	Crest (mAOD)	Maximum Opening (m)	Peak 100yr Do Min WL	Clearance (m)
Kings Large Buck Gates	50.BGAU	Vertical Sluice	56.990	3.150	59.46	0.68
Kings Medium Buck Gates	50.BGBU	Vertical Sluice	56.990	3.150	59.46	0.68
Kings Rymer Weir	50.LAU	Vertical Sluice	58.520	1.500	59.46	0.56
Wolvercote Radial Gates	48f.NWU	Radial Sluice	58.020	2.000	58.66	1.36
Godstow Weir A	49.003	Radial Sluice	55.425	3.325	58.48	0.27
Godstow Weir B	49b.009C	Vertical Sluice	56.888	2.550	58.59	0.85
Osney Bridge Bucks	47q.BGU	Vertical Sluice	54.650	3.500	57.23	0.92
Osney Hand Radial	48.HRU	Radial Sluice	55.666	2.250	57.10	0.82
Osney Tilting Gate	48.TU	Gated Weir	54.080	0.000	57.08	n/a
Iffley West Weirs Mill	46h.040R	Radial Sluice	53.450	3.550	55.73	1.27
Iffley East Weirs Mill	46h.DRBU	Radial Sluice	53.390	3.500	55.75	1.14
Iffley Rymer Weir A	47.RYU	Vertical Sluice	53.730	2.620	55.62	0.73
Iffley Buck Gate Weir A	47.BGU	Vertical Sluice	52.170	4.000	55.62	0.55
Iffley Buck Gate Weir B	47.BGUA	Vertical Sluice	52.800	2.800	55.68	-0.08
Sandford Hand Radial	46.HRU	Radial Sluice	53.190	2.110	54.55	0.75
Sandford Hand Radial	46.DRU	Radial Sluice	51.360	3.500	54.55	0.31

6.3 Representing Do Minimum and Do Nothing

Technical note IMSE500177-HGL-00-ZZ-RE-N-000078 contains full details and commentary on the assumptions for the Do Minimum and Do Nothing scenarios. A summary table of the assumptions is included as Appendix B.

For modelling purposes, the Do Minimum scenario includes:

- The continued operation, maintenance and repair of all sluices and flow control structures.
- Carrying out any damage limitation or flood alleviation measures during flood events (including the deployment of temporary flood defences and delivery of flood warnings). Note that the temporary defences are not used for the year 2035 Do Minimum scenario.

The Do Nothing scenario includes:

- The abandonment of all locks and control structures. Locks and sluice gates are left closed.
- The cessation of all maintenance to watercourses (e.g. debris / vegetation clearance)
- Not carrying out other measures during flood events (e.g. deploying temporary defences etc.)

The models have been set up to represent 2 time frames for Do Minimum models and 3 time frames for Do Nothing, as detailed in Table 14. The 2D model files are the same for all scenarios, apart from the removal of the 2D defences (2d_zsh_temp_defences.shp) and roughness stability patch (2d_mat_stability_DN.shp) which is required for the Do Nothing year 20 and 50 scenario.

Full details of the models files required for the Do Minimum and Do Nothing scenarios are included in Appendix C

Table 14: Do Minimum and Do Nothing Models

Scenario	1D Model Datafile	Summary of model
Do Minimum Year 0 (2015)	Ox_DM2015.DAT	Current conditions model. Includes temporary defences in 2D (2d_zsh_temp_defences.shp)
Do Minimum Year 35 (2050)	Ox_DM2015.DAT	Same 1D model as Year 0. Temporary defences removed from 2D model
Do Nothing Year 0 (2015)	Ox_DN2015.DAT	Temporary defences removed from 2D model Sluices at Osney, Iffley, Sandford, Weirs Mill and Castle Mill Weir closed
Do Nothing Year 20 (2035)	Ox_DN2035.DAT	Temporary defences removed from 2D model Sluices at Osney, Iffley, Sandford, Weirs Mill and Castle Mill Weir closed Manning's 'n' for Thames increased by 50% for vegetation and a further 20% to reflect siltation (reducing cross section area by approximately 10%) Other watercourses increased by 100% for vegetation and a further 33% to reflect siltation (reducing cross section area by approximately 20%) 30% bridge blockage (Bernoulli 'k' increase by 100%) and 50% Blockage (Bernoulli 'k' increase by 300% and blockage units)
Do Nothing Year 50 (2065)	OX_DN2065.dat	Temporary defences removed from 2D model Sluices at Osney, Iffley, Sandford, Weirs Mill and Castle Mill Weir open Manning's 'n' for Thames increased by 50% for vegetation and a further 67% to reflect siltation (reducing cross section area by approximately 25%) Other watercourses increased by 100% for vegetation and a further 100% to reflect siltation (reducing cross section area by approximately 45%) 30% bridge blockage (Bernoulli 'k' increase by 100%) and 50% Blockage (Bernoulli 'k' increase by 300% and blockage units)

6.4 Using roughness to simulate the effects of siltation

To quantify the increase in roughness used to represent siltation for the Do Nothing scenarios, modelling was undertaken on sample reaches of the Thames and Hinksey Stream. Each reach assumed a bank full flow and was run with the increased roughness values for siltation as defined for year 20-49 (2035 – 2064) and 50-99 (2065 – 2114) (Appendix B). The models using the base roughness value (before increase for siltation), were then modified by increasing bed levels by 0.1m intervals until the model predicted water levels similar to those with the increased roughness.

Table 15 summarises the results, which show that for years 20-49 (2035 – 2064), roughness increases on the Thames and Hinksey Stream of 20% to 33% are equivalent to increasing the bed level by 0.3m resulting in a reduced cross section area of 10% to 20%. For year 50-99 (2065 – 2114), roughness increases of 67% to 100% are equivalent to increasing the bed level by 0.7 to 0.8m resulting in a reduced cross section area of 25% to 45%.

Table 15: Quantifying roughness to represent siltation

Watercourse/Reach	Increase in roughness to reflect siltation	Equivalent increase in channel bed level	% Reduction in cross sectional area
Thames Y20-Y49	20%	0.3m	10%
Thames Y50-Y99	67%	0.7m	25%
Hinksey Stream Y20-Y49	33%	0.3m	20%
Hinksey Stream Y50-Y99	100%	0.8m	45%

Table 16 summarises the manning's 'n' values used for the Do Nothing scenarios to represent the effects of vegetation and siltation.

Table 16: Summary of 1D Roughness values (Manning's n) for Do Nothing

Watercourse/Reach	Year 0 (2015)	Year 20 (2035)	Year 50 (2065)
Thames upstream of Kings Lock	0.036	0.065	0.090
Thames - Kings to Godstow Lock	0.036/0.042	0.065/0.076	0.090/0.105
Thames - Godstow to Osney Lock	0.034/0.042	0.061/0.076	0.085/0.105
Thames - Osney to Iffley Lock	0.036	0.061	0.085
Thames - Iffley to Sandford Lock	0.042	0.076	0.105
Thames – d/s Sandford Lock	0.036	0.065	0.090
Weirs Mill Stream	0.042	0.112	0.168
Bulstake Stream	0.050	0.133	0.200
Seacourt Stream	0.050/0.080	0.133/0.213	0.200/320
Botley Stream	0.050	0.133	0.200
Osney Ditch	0.050/0.080	0.133/0.213	0.200/320
Osney Stream	0.045	0.120	0.180
Hinksey Stream	0.050	0.133	0.200
Hinksey Ditch	0.050	0.133	0.200
Redbridge Stream	0.050	0.133	0.200
Castle Mill Stream	0.036/0.042	0.065/0.076	0.090/0.105
Wolvercote Stream	0.043	0.114	0.172
Eastwyke Ditch	0.050	0.133	0.200
River Cherwell	0.042	0.112	0.168

6.4.1 Model Simulations/Performance (Do minimum/nothing scenarios)

The Do Minimum and Do Nothing scenario has been run for the full range of design events (refer to Table 1 for target flow at Sandford). The model simulations do not include any allowance for climate change for the future scenarios, the effect of climate change is assessed in the economic analysis.

The model runs satisfactorily with minimal divergence for the Do Minimum and Do Nothing events.

For the Do Minimum scenario stability problems are flagged for the 1000 year event. In the model they are located around a bridge in Osney Ditch (OD01.014, 36 – 45hrs) and Bulstake Stream (BS01.056, 130 and 150hrs) when floodplain flows spill into the ditch downstream of the bridge and the bridges are transitioning to orifice flow regimes. The level plots do not show any impacts on peak levels. Figure 12 details the convergence plots produced as part of the 1D model outputs for the 1000 year Do Minimum event. The figure also includes a graph of flows and levels at the nodes location flagged in the diagnostics output, which show the smooth water levels (blue lines), without any spikes which could impact the results. These checks suggest that the model stability issue does not affect the results.

For the Do Nothing scenario stability problems are flagged for the 1000 year event on Bulstake Stream at the same bridge which flagged non-convergence for Do Minimum (Node BS01.056), where checks showed the model stability issue does not affect the results. Figure 13 details the convergence plots produced as part of the 1D model outputs for the 1000 year Do Nothing event

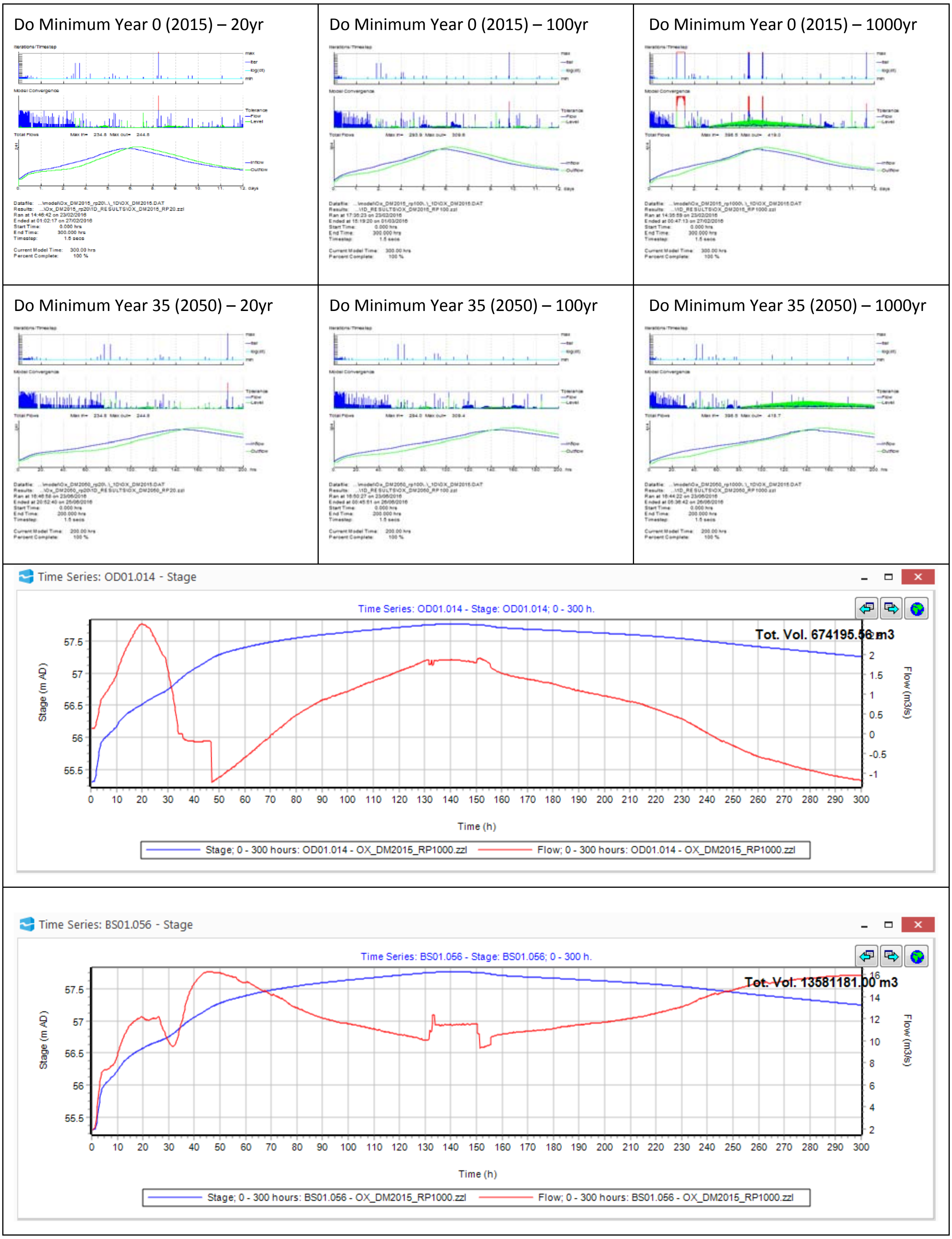


Figure 12: 1D convergence plots – Do Minimum

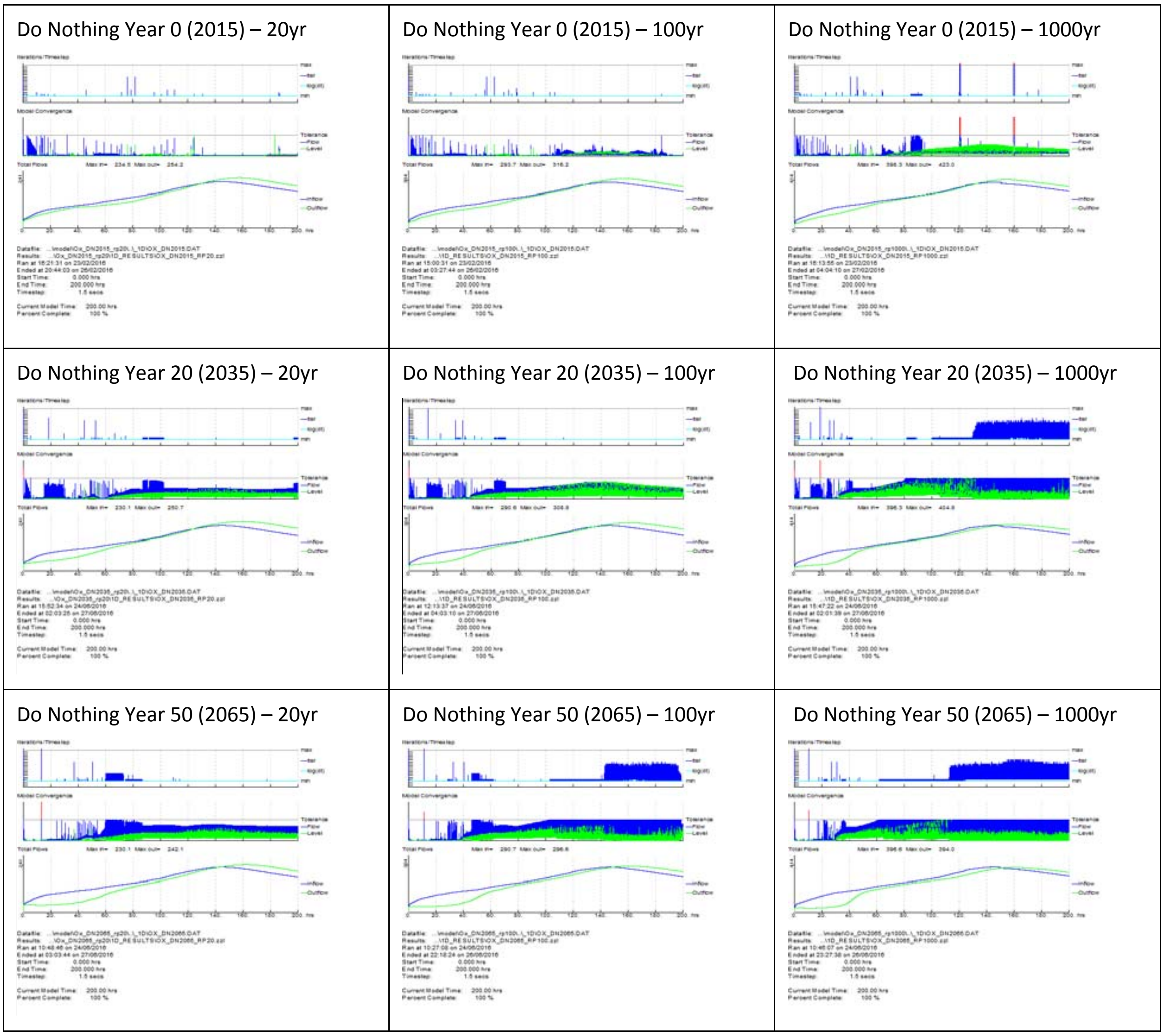


Figure 13: 1D convergence plots – Do Nothing

A sample range of the 2D output of cumulative mass errors have values (within +/- 1%) and dVol (smooth plots) are detailed in Figure 14. These detail the outputs for all scenarios for the 100 year event. The initial spike on the dVol plot is due to higher 1D initial water levels due to the gate closure and roughness increase for the Do Nothing scenario, resulting in spilling to the 2D model when the simulation starts.

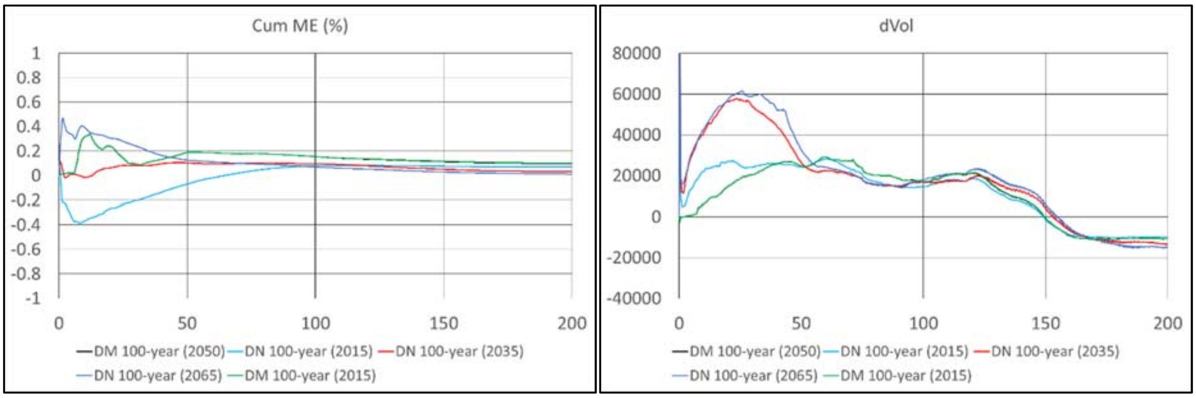


Figure 14: 2D Cumulative Mass Error and dVol (Do Minimum/Nothing)

6.5 Results – Do Minimum

Peak water levels at telemetry stations from the 'Do Minimum' current conditions model are detailed in Table 17. Figure 15 compares the 100 year flood extents with Environment Agency Flood Zones. Generally the flood extents have increased under the new model, due to a combination of the model updates and increased inflow following the hydrological assessment. Table 18 compares the 100 year peak water levels to the previous study, which was used to define the Flood Zone maps (2014 Oxford Flood Risk Mapping Study).

Table 17: Peak water levels (mAOD) - Do Minimum

Location (model node)	**2**	**5**	**10**	**20**	**50**	**75**	**100**	**200**	**1000**
Kings Lock Head (50.008)	59.32	59.43	59.48	59.52	59.56	59.57	59.59	59.62	59.70
Kings Lock Tail (49.050)	58.96	59.06	59.11	59.15	59.19	59.21	59.23	59.28	59.45
Godstow Lock Head (49.003U)	58.17	58.21	58.27	58.33	58.41	58.45	58.48	58.57	58.87
Godstow Lock Tail (48.085)	57.78	57.86	57.92	57.97	58.04	58.06	58.08	58.13	58.22
Osney Lock Head (48.HRU)	56.57	56.68	56.80	56.89	57.01	57.06	57.10	57.18	57.34
Osney Lock Tail (47.125)	55.99	56.21	56.34	56.42	56.53	56.58	56.61	56.69	56.86
Iffley Lock Head (TH47_003)	55.03	55.29	55.43	55.54	55.65	55.69	55.73	55.79	56.01
Iffley Lock Tail (46.052)	54.70	54.96	55.09	55.20	55.35	55.41	55.46	55.58	55.89
Sandford Lock Head (46c_002A)	54.15	54.31	54.38	54.44	54.53	54.57	54.60	54.68	54.87
Sandford Lock Tail (45.164)	53.33	53.59	53.75	53.87	54.03	54.10	54.15	54.28	54.58
Minns Estate (47m.26B)	56.74	56.92	57.01	57.08	57.16	57.19	57.21	57.26	57.40
New Botley (47k.017)	56.68	56.95	57.08	57.17	57.26	57.31	57.34	57.40	57.58
Cold Harbour (46g.012C)	55.05	55.51	55.82	55.98	56.18	56.24	56.28	56.34	56.49
Ice Rink (47f.103F)	55.80	56.00	56.15	56.26	56.39	56.45	56.48	56.56	56.73
Cherwell (CH.014)	55.70	55.90	56.00	56.08	56.17	56.21	56.23	56.29	56.46

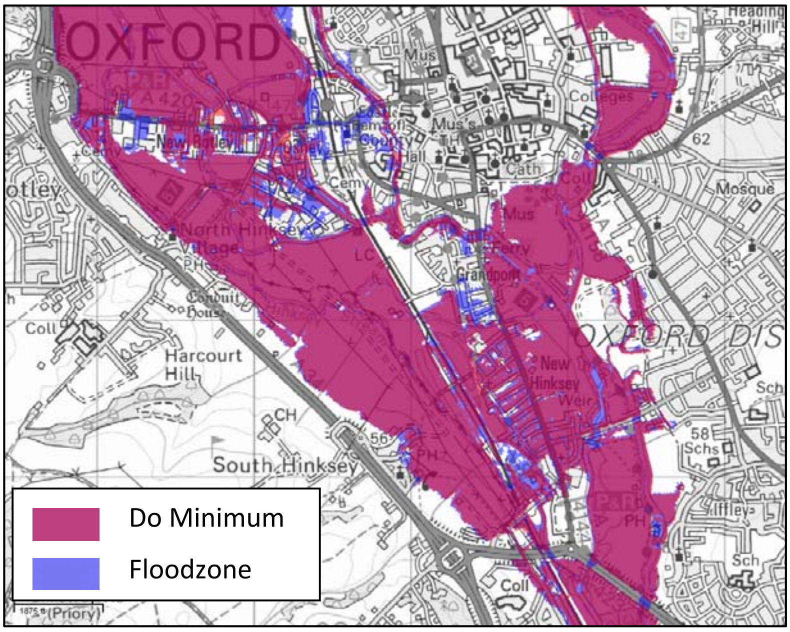


Figure 15: Comparison between floodzone and Oxford FAS Do Minimum extents (100 year)

Table 18: Peak water levels (mAOD) – 100 year comparison to previous study

Location (model node)	Do Minimum (Y0, 2015)	2014 Oxford Flood Risk Mapping Study - Peak WL and difference (m) to Do Minimum	
Kings Lock Head (50.008)	59.59	59.54	0.04
Kings Lock Tail (49.050)	59.23	59.16	0.07
Godstow Lock Head (49.003U)	58.48	58.42	0.06
Godstow Lock Tail (48.085)	58.08	58.04	0.05
Osney Lock Head (48.HRU)	57.10	56.97	0.13
Osney Lock Tail (47.125)	56.61	56.53	0.08
Iffley Lock Head (TH47_003)	55.73	55.64	0.09
Iffley Lock Tail (46.052)	55.46	55.35	0.11
Sandford Lock Head (46c_002A)	54.60	54.48	0.13
Sandford Lock Tail (45.164)	54.15	54.15	0.00
Minns Estate (47m.26B)	57.21	57.00	0.21
New Botley (47k.017)	57.34	57.35	0.00
Cold Harbour (46g.012C)	56.28	56.10	0.17
Ice Rink (47f.103F)	56.48	56.42	0.06
Cherwell (CH.014)	56.23	56.23	0.01

Table 19 compares the peak water levels for the Do Minimum year 0 and year 35 scenarios for the 20 and 100 year events. The model predicts a reduction in peak water level for the year 35 scenario at Osney. This is due the removal of the temporary defences in year 35, particularly as Osney Island.

Table 19: Peak water levels (mAOD) - Do Minimum year 0 and 35 comparison

Location (model node)	20 year			100 year		
	Y0, 2015	Y35, 2050	Diff (m)	Y0, 2015	Y35, 2050	Diff (m)
Kings Lock Head (50.008)	59.52	59.52	0.00	59.59	59.59	0.00
Kings Lock Tail (49.050)	59.15	59.15	0.00	59.23	59.23	0.00
Godstow Lock Head (49.003U)	58.33	58.33	0.00	58.48	58.48	0.00
Godstow Lock Tail (48.085)	57.97	57.97	0.00	58.08	58.08	0.00
Osney Lock Head (48.HRU)	56.89	56.88	-0.02	57.10	57.06	-0.04
Osney Lock Tail (47.125)	56.42	56.42	0.00	56.61	56.61	0.00
Iffley Lock Head (TH47_003)	55.54	55.54	0.00	55.73	55.73	0.00
Iffley Lock Tail (46.052)	55.20	55.20	0.00	55.46	55.46	0.00
Sandford Lock Head (46c_002A)	54.44	54.44	0.00	54.60	54.60	0.00
Sandford Lock Tail (45.164)	53.87	53.87	0.00	54.15	54.15	0.00
Minns Estate (47m.26B)	57.08	57.08	0.00	57.21	57.21	-0.01
New Botley (47k.017)	57.17	57.17	0.00	57.34	57.34	-0.01
Cold Harbour (46g.012C)	55.98	55.98	0.00	56.28	56.27	0.00
Ice Rink (47f.103F)	56.26	56.26	0.00	56.48	56.48	0.00
Cherwell (CH.014)	56.08	56.08	0.00	56.23	56.23	0.00

6.6 Results – Do Nothing

Peak water levels at telemetry stations for the 'Do Nothing' scenarios are detailed in Table 20 (5 year), Table 21 (20 year) and Table 22 (100 year), the tables include additional locations in the floodplain at detailed in Figure 16. Commentary on the results are included with each results table, to explain the effect of each scenario for year 0, 20 and 50. The Do Nothing scenarios are summarised below (full details in section 6.3 and Appendix D).

- DN Year 0 (2015) Temporary defences removed. Sluices at Osney, Iffley, Sandford, Weirs Mill & Castle Mill closed
- DN Year 20 (2035) As Year 0, with increased vegetation, siltation and blockages to bridges
- DN Year 50 (2065) As Year 20, with further increase in siltation and sluices at Osney, Iffley, Sandford, Weirs Mill and Castle Mill Weir open

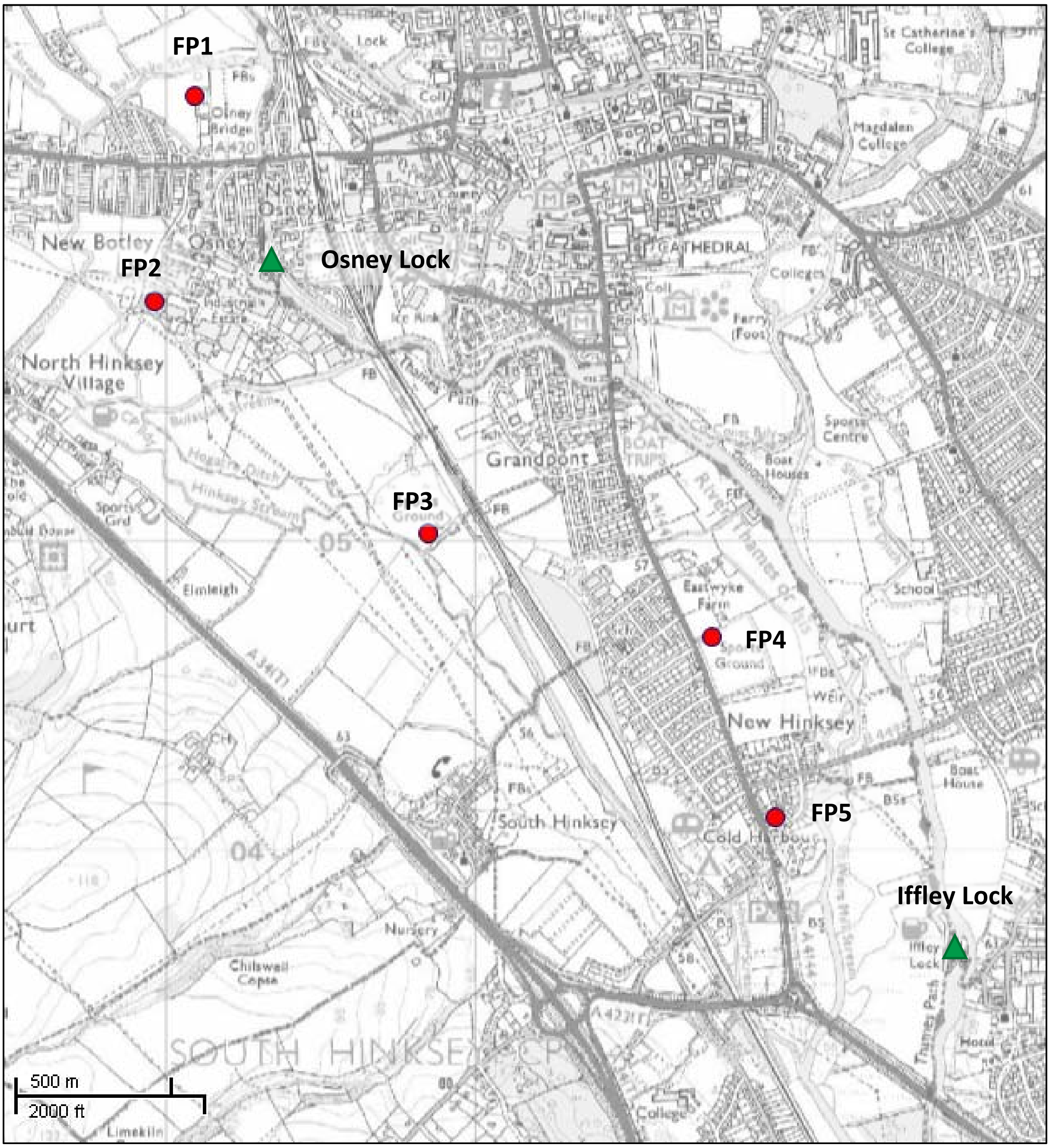


Figure 16: Do Nothing floodplain reporting locations

5 Year

DN Year 0 (2015) — As expected, the largest increase in peak water levels are located upstream of the Thames weir structures which are closed for the scenario, levels are shown to rise by a maximum of 0.54m at Osney. This pushes more flow into the western floodplain increasing levels on the Bulstake/Seacourt Streams down to Cold Harbour, where levels rise by 0.24m. Within the floodplain, levels increase by 0.07 to 0.28m.

DN Year 20 (2035) — The increased vegetation\siltation and blockages to bridges raises the levels throughout the system with the largest increases (compared to DN Year 0) on the downstream side of the weir structures (Iffley +0.49m), levels in the floodplain increase by a further 0.18 to 0.42m.

DN Year 50 (2065) — The effect of opening the Thames weir structures which were closed for the Year 0 and 20 scenarios reduces levels upstream of these structures (Osney, Iffley and Sandford) compared to DN Year 20. Within the channels the largest increase in level is downstream of Iffley, with a further increase of 0.29m. Levels in the floodplain increase by a further 0.01 to 0.14m.

Table 20: Peak water levels (mAOD) - Do Nothing 5 year

Location	DM - Y0 2015	DN - Y0 2015	Diff (m) to DM	DN - Y20 2035	Diff (m) to DM	Diff (m) to DN Y0	DN - 50 2065	Diff (m) to DM	Diff (m) to DNY 20
Kings Head	59.43	59.43	0.00	59.46	0.03	0.03	59.48	0.05	0.01
Kings Tail	59.06	59.06	0.00	59.24	0.18	0.18	59.27	0.21	0.04
Godstow Head	58.21	58.21	0.00	58.20	-0.01	-0.01	58.22	0.00	0.01
Godstow Tail	57.86	57.87	0.01	58.08	0.22	0.21	58.14	0.27	0.06
Osney Head	56.68	57.22	0.54	57.35	0.67	0.13	57.02	0.33	-0.34
Osney Tail	56.21	56.25	0.03	56.64	0.43	0.40	56.77	0.56	0.13
Iffley Head	55.29	55.77	0.48	55.77	0.49	0.00	55.85	0.57	0.08
Iffley Tail	54.96	55.03	0.08	55.52	0.56	0.49	55.81	0.85	0.29
Sandford Head	54.31	54.71	0.41	54.66	0.36	-0.05	54.39	0.09	-0.27
Sandford Tail	53.59	53.60	0.01	54.01	0.41	0.40	54.15	0.56	0.15
Minns Estate	56.92	57.02	0.09	57.24	0.31	0.22	57.24	0.31	0.00
New Botley	56.95	57.10	0.15	57.45	0.50	0.36	57.44	0.49	-0.01
Cold Harbour	55.51	55.76	0.24	56.38	0.87	0.63	56.45	0.94	0.07
Ice Rink	56.00	56.09	0.09	56.43	0.43	0.34	56.58	0.57	0.15
Cherwell	55.90	56.02	0.12	56.36	0.46	0.34	56.53	0.63	0.17
FP 1	57.13	57.31	0.17	57.64	0.50	0.33	57.69	0.56	0.05
FP 2	56.56	56.64	0.07	56.82	0.25	0.18	56.83	0.27	0.01
FP 3	56.02	56.14	0.12	56.56	0.54	0.42	56.63	0.61	0.07
FP 4	55.57	55.84	0.27	56.04	0.47	0.20	56.18	0.61	0.14
FP 5	55.50	55.78	0.28	55.93	0.43	0.15	56.05	0.55	0.12

20 Year

DN Year 0 (2015)	As expected, the largest increase in peak water levels are located upstream of the Thames weir structures which are closed for the scenario, levels are shown to rise by a maximum of 0.44m at Osney. This pushes more flow into the western floodplain increasing levels on the Bulstake/Seacourt Streams down to Cold Harbour, where levels rise by 0.08m. Within the floodplain, levels increase by 0.05 to 0.13m
DN Year 20 (2035)	The increased vegetation\siltation and blockages to bridges raises the levels throughout the system with the largest increases (compared to DN Year 0) on the downstream side of the weir structures (Iffley +0.58m), levels in the floodplain increase by a further 0.16 to 0.35m.
DN Year 50 (2065)	The effect of opening the Thames weir structures which were closed for the Year 0 and 20 scenarios reduces levels upstream of these structures (Osney, Iffley and Sandford) compared to DN Year 20. Within the channels the largest increase in level is downstream of Iffley, with a further increase of 0.31m. Levels in the floodplain increase by a further 0.02 to 0.24m.

Table 21: Peak water levels (mAOD) - Do Nothing 20 year

Location	DM - Y0 2015	DN - Y0 2015	Diff (m) to DM	DN - Y20 2035	Diff (m) to DM	Diff (m) to DN Y0	DN - 50 2065	Diff (m) to DM	Diff (m) to DN Y20
Kings Head	59.52	59.52	0.00	59.53	0.02	0.02	59.56	0.04	0.02
Kings Tail	59.15	59.15	0.00	59.30	0.16	0.16	59.37	0.23	0.07
Godstow Head	58.33	58.33	0.00	58.33	0.01	0.01	58.33	0.01	0.00
Godstow Tail	57.97	57.99	0.02	58.18	0.21	0.19	58.23	0.26	0.05
Osney Head	56.89	57.33	0.44	57.44	0.55	0.11	57.15	0.26	-0.29
Osney Tail	56.42	56.42	0.00	56.78	0.35	0.36	56.90	0.48	0.12
Iffley Head	55.54	55.83	0.28	55.90	0.36	0.08	56.17	0.63	0.27
Iffley Tail	55.20	55.25	0.05	55.83	0.63	0.58	56.14	0.94	0.31
Sandford Head	54.44	54.78	0.34	54.74	0.30	-0.04	54.61	0.16	-0.13
Sandford Tail	53.87	53.87	0.00	54.26	0.38	0.38	54.40	0.52	0.14
Minns Estate	57.08	57.14	0.06	57.35	0.27	0.21	57.36	0.28	0.01
New Botley	57.17	57.25	0.08	57.58	0.41	0.32	57.55	0.38	-0.02
Cold Harbour	55.98	56.06	0.08	56.48	0.49	0.41	56.55	0.56	0.07
Ice Rink	56.26	56.28	0.02	56.58	0.32	0.30	56.73	0.47	0.15
Cherwell	56.08	56.14	0.05	56.53	0.45	0.40	56.76	0.68	0.23
FP 1	57.37	57.46	0.09	57.76	0.39	0.30	57.80	0.43	0.04
FP 2	56.70	56.75	0.05	56.91	0.21	0.16	56.93	0.23	0.02
FP 3	56.28	56.33	0.05	56.68	0.40	0.35	56.74	0.46	0.06
FP 4	55.82	55.95	0.13	56.22	0.40	0.27	56.44	0.61	0.21
FP 5	55.76	55.86	0.09	56.08	0.32	0.23	56.32	0.56	0.24

100 Year

DN Year 0 (2015)	As expected, the largest increase in peak water levels are located upstream of the Thames weir structures which are closed for the scenario, levels are shown to rise by a maximum of 0.35m at Osney. This pushes more flow into the western floodplain increasing levels on the Bulstake/Seacourt Streams down to Cold Harbour, where levels rise by 0.02m. Within the floodplain, levels increase by 0.02 to 0.06m
DN Year 20 (2035)	The increased vegetation\siltation and blockages to bridges raises the levels throughout the system with the largest increases (compared to DN Year 0) on the downstream side of the weir structures (Iffley +0.66m), levels in the floodplain change by -0.02 to 0.20m.
DN Year 50 (2065)	The effect of opening the Thames weir structures which were closed for the Year 0 and 20 scenarios reduces levels upstream of these structures (Osney, Iffley and Sandford) compared to DN Year 20. Within the channels the largest increase in level is downstream of Iffley, with a further increase of 0.32m. Levels in the floodplain increase by a further 0.04 to 0.27m.

Table 22: Peak water levels (mAOD) - Do Nothing 100 year

Location	DM - Y0 2015	DN - Y0 2015	Diff (m) to DM	DN - Y20 2035	Diff (m) to DM	Diff (m) to DN Y0	DN - 50 2065	Diff (m) to DM	Diff (m) to DN Y20
Kings Head	59.59	59.59	0.00	59.62	0.03	0.03	59.65	0.07	0.03
Kings Tail	59.23	59.23	0.00	59.43	0.20	0.20	59.51	0.28	0.08
Godstow Head	58.48	58.48	0.00	58.47	-0.02	-0.02	58.44	-0.04	-0.02
Godstow Tail	58.08	58.09	0.01	58.27	0.19	0.18	58.31	0.23	0.04
Osney Head	57.10	57.45	0.35	57.52	0.42	0.07	57.30	0.20	-0.22
Osney Tail	56.61	56.59	-0.02	56.91	0.30	0.31	57.05	0.44	0.14
Iffley Head	55.73	55.88	0.16	56.21	0.48	0.33	56.52	0.79	0.31
Iffley Tail	55.46	55.50	0.04	56.16	0.70	0.66	56.48	1.02	0.32
Sandford Head	54.60	54.87	0.27	54.81	0.21	-0.05	54.78	0.18	-0.03
Sandford Tail	54.15	54.15	0.00	54.52	0.36	0.36	54.66	0.50	0.14
Minns Estate	57.21	57.26	0.04	57.48	0.26	0.22	57.50	0.28	0.02
New Botley	57.34	57.40	0.05	57.70	0.36	0.30	57.67	0.33	-0.02
Cold Harbour	56.28	56.29	0.02	56.59	0.31	0.30	56.74	0.47	0.15
Ice Rink	56.48	56.48	0.00	56.75	0.27	0.27	56.93	0.45	0.18
Cherwell	56.23	56.26	0.03	56.76	0.53	0.50	57.01	0.78	0.25
FP 1	57.55	57.60	0.06	57.87	0.33	0.03	57.92	0.27	0.04
FP 2	56.81	56.86	0.04	57.01	0.20	0.20	57.07	0.16	0.05
FP 3	56.50	56.52	0.02	56.80	0.29	-0.02	56.89	0.28	0.09
FP 4	56.01	56.07	0.06	56.49	0.48	0.18	56.73	0.42	0.24
FP 5	55.90	55.94	0.04	56.36	0.46	0.07	56.63	0.42	0.27

6.7 Checks following Peer Review 3

6.7.1 Osney Island – Temporary Defences

The schematisation of the temporary defences around Osney Island were checked following comments on the low standard of protection. The Do Minimum model (including the temporary defences) predicts flooding in Osney Island for the 10 year event as shown in Figure 17. The flow path predicted by the model is located through the gardens of Doyley Road below the temporary defences on South Street. Table 23 details the peak water levels at Osney and the recent 2014 event when temporary defences were deployed, which show the model 2014 level at Osney Tail is lower than the 10 year event (although the modelled level is lower than the telemetry)

Table 23: Peak water levels (mAOD) – Osney

Location (model node)	2	5	10	20	2014 (telemetry)	2014 (modelled)
Osney Lock Head (48.HRU)	56.57	56.68	56.80	56.89	56.70	56.70
Osney Lock Tail (47.125)	55.99	56.21	56.34	56.42	56.45	56.30

Figure 17: Osney Island Flood Extents – 10 year
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The following comment from the EA describes the flood regime in this area:

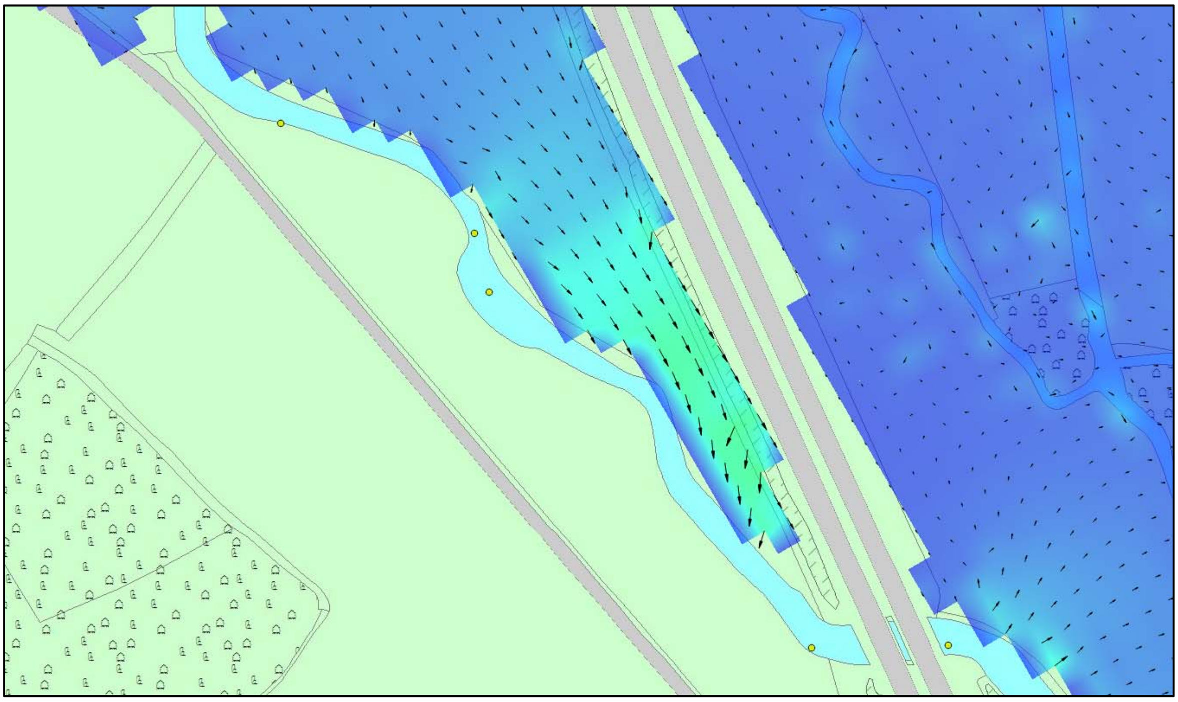
'Historically, water has started coming up through surface water drains before any of the defences have got wet. There is a particular location just outside the gates the Environment Agency Depot at Osney Yard where water tends to pool. We drop a pump into a manhole here to keep levels down. After the surface water drains backing up, the first fluvial flooding we're normally aware of is at the

low point on West Street. Next comes South Street and then finally East Street. The gardens in the vicinity of Doyley Road flood but we haven't see evidence of a flow route through this area since we have been using the temporary barriers. Prior to the use of temporary barriers (and pumps), large parts of the Island would have already been underwater (e.g. 2007 flood) before any Doyley Road flow route was mobilised, so it would have probably been difficult to identify this'.

Comparison of the model predictions and the Environment Agency's comments, indicates that the model is close to replicating the flooding in this area. The bank levels used at Doyley Road are based on LiDAR due to the lack of any other survey, and could possibly be slightly higher (less than 0.1m) if the telemetry level recorded for 2014 is correct and no flooding occurred. Given the differences are within the accuracy tolerance of the model, changes to the schematisation are not required.

6.7.2 Seacourt Stream A34 Sensitivity

Following the Oxford FAS model Peer review 3, the water surface profile of the Seacourt Stream where it flows under the A34 was reviewed. The reason for the water surface slope is due to the total flows in the Seacourt Stream and floodplain converging before flowing under the A34. The 1000-year peak water level at the bridge is 58.11m (soffit level 58.81m), the bridge opening is twice the size of the Seacourt Stream. Details of the surface profile and converging of flows upstream of the bridge are detailed in Figure 18.



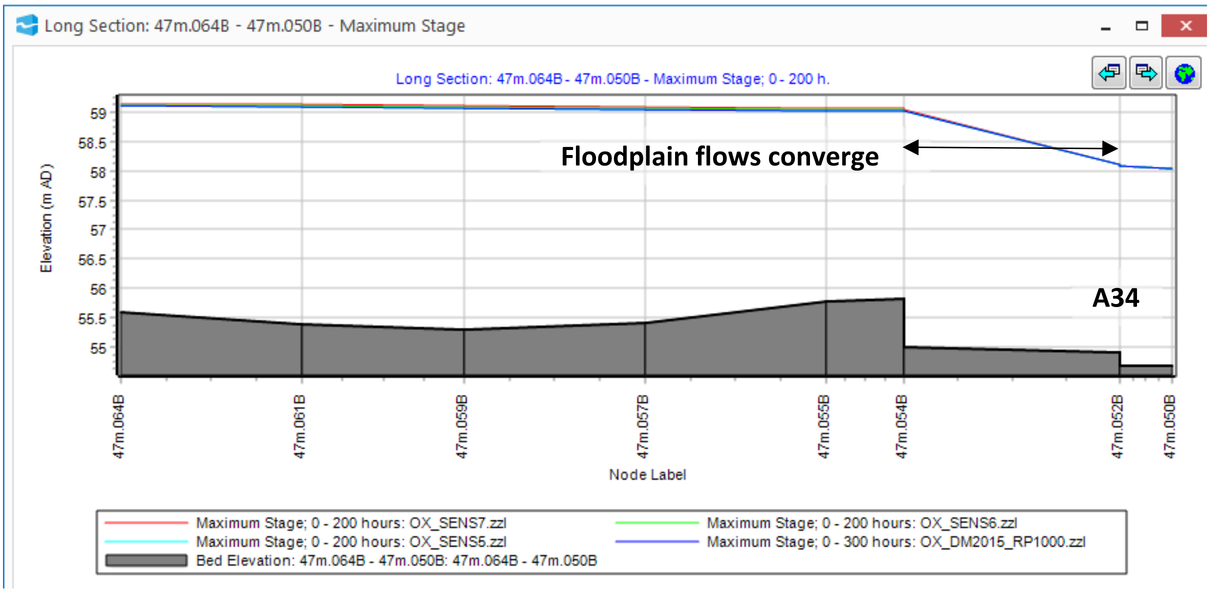


Figure 18: Seacourt Stream A34

A series of sensitivity tests have been undertaken to test the model in this location

1. HX energy loss increase to 1.5
2. As test 1 and 2D local roughness increase (from 0.050 to 0.10)
3. As test 2 and adjustment to bridge cross section to remove abutments (although the section is already larger than the typical stream size)

The results of the tests, show a maximum reduction in peak water level of 0.03m which is localised to the section upstream of the water surface slope. Between Kings and Godstow Locks, there is a 0.01m reduction, otherwise the model predicts negligible changes in water level. Appendix D details the peak water levels at all telemetry stations and the flows though the A34 for each test.

Outline Design Modelling

7.1 Initial outline design (April 2016)

An initial model representing options for the outline design was schematised and reported in April 2016. The model included the preferred elements of the FAS, but at that stage did not consider bridge and culvert structures.

The April 2016 technical report 'IMSE500177-HGL-00-ZZ-RE-N-000102' can be referenced for information of the initial outline design. However, there have been significant changes following environmental and engineering design considerations and constraints identified. Therefore, the initial outline design is now largely superseded by the outline design presented in this report.

7.2 Overview of the outline design model

The preferred option model was developed from the previously reported 'Do Minimum' and builds on the initial outline design model. The majority of the elements of the option are represented within the 1D model, with the 2D model used to represent features such as embankments and provide the 1D-2D linking of new channels. Figure 19 details the areas of the individual elements which make up the preferred option. Full details of the models files required for outline design model are included in Appendix E.

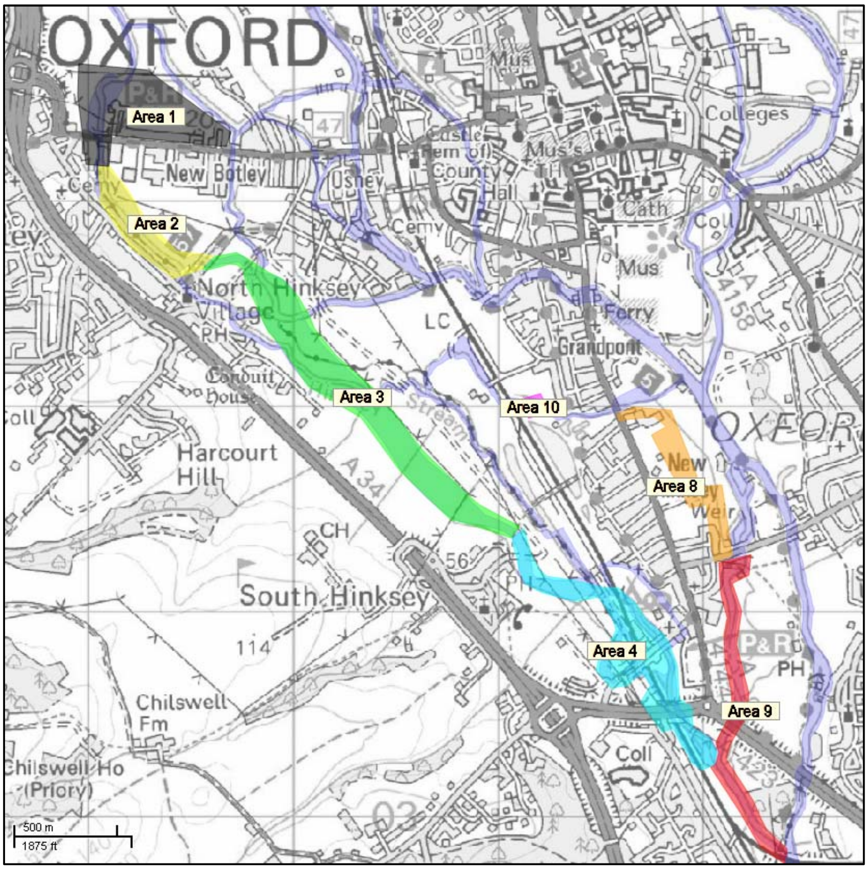


Figure 19: Model extent and key locations

The individual elements which provide the outline design model are summarised in Table 24. The following section of the report provides further details of the model schematisation for each area.

Table 24: Elements of the Outline Design

Area	Key features of the preferred option	
1	**Botley Road Area** • 2-stage channel on Seacourt Stream left bank from nodes SS-01799 to SS-01541. • Right bank stepped channel extending out to existing ground levels with bed clearance from nodes SS-01517 to SS-01391. • Channel widening d/s of Botley Road (Nodes 47m.28S to SS-200), including new access bridge (SS-100). Roughness reduced to 0.040 to represent channel improvements. • Embankments u/s Botley Road and on left and right banks. • Defence on Osney Ditch adjacent to Helen Road (Defence on right bank)	Refer to Table 25
2	**Botley Road to Willow Walk** • New 1m deep scrape channel (Nodes 2B_000 to 2B_215) • Seacourt Stream and new channel combined with low bank (potential access) between channels. (Nodes 2B_215d to 2B_530u). • New channel separates to constrained section for new bridge at Willow Walk). • Existing culverts under Willow Walk removed.	Refer to Table 26
3	**Willow Walk to Devil's Backbone** • New constrained channel with new access bridge (3A_0201bu), typical depth 1.8m. • New 2-stage channel, (Nodes 3A_0210 to 3A_1975). Typical channel depth of 0.5m on second stage with 1m deep channel (total depth 1.5m). • New constrained channel with new access bridge at Devils Backbone (3A_2095bu), typical channel depth of 1.6m.	Refer to Table 27
4	**Devil's Backbone to Mundays Bridge** • New 2-stage channel Devil's Backbone to Railway including new access bridge (4A_105bu) and ford crossing (4A_455). Typical channel depth of 0.4m on second stage with 1m deep channel (total depth 1.4m). • Widening of existing channels down to new channel, bed levels 53.6m to 53.5m. • New constrained channel with bed levels of 53.5m to 52.7m, channel width increases from 25m to maximum of 55m around bend, total depth 1.5 – 2m. • New triple culvert at Abingdon road, with flood bund or headwall. • Network Rail Culvert. • Channel improvements Hinksey Stream from Network Rail Culvert to Mundays Bridge. • Towles Mill weir removed, both the rock weir and the bulk of the main gated weir. Review of any historical interest in the EIA process during the detailed design. • Flow control to Redbridge ditch. • Re-profiling of ditch from new Abingdon Road culvert to Mundays Bridge. Constrained between railway/pylons and under A423. • New channel and culvert under A423. Culvert 8m x 3.5m (both sides of railway)	Refer to Table 28 Refer to Table 29
8	**New Hinksey** • Embankment from Hotel to Donnington Road • Park Embankment	Refer to Table 30
9	**Weir Mill Stream and Hinksey Stream to River Thames (Railway Bridge)** • Improved channel conveyance	Refer to Table 31
10	**Eastwyke Ditch** • Control structure east of the railway culvert to restrict flow to the Thames	Refer to Table 32

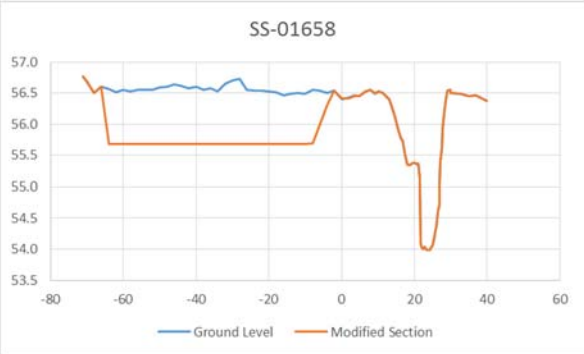
7.3 Model schematisation of outline design

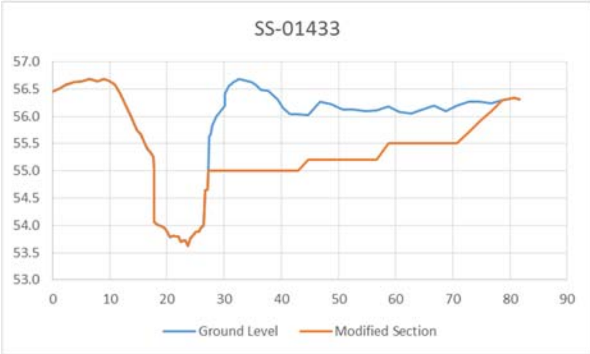
Table 25 to Table 32 detail the schematisation of the model in each area for outline design model.

Table 25: Area 1 model schematisation

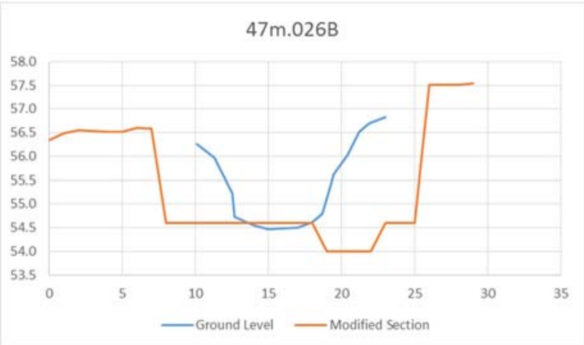
Area	Key features of the preferred option *(model nodes or 2D feature)*
1	**Botley Road Area**
	A. 2-stage channel on Seacourt Stream left bank from nodes SS-01799 to SS-01541. Second stage approximately 0.75m deep, area next to the bank as existing due to trees. No changes to original bed levels.
	B. Right bank stepped channel extending out to existing ground levels from nodes SS-01517 to SS-01391. Left bank no change, clearance to hard bed levels to Botley Road Bridge (Node SS-01517 to SS-01391).
	C. Channel widening d/s of Botley Road (Nodes 47m.28S to SS-200), including new access bridge (SS-100). Roughness reduced to 0.040 to represent channel improvements.
	D. Embankment adjacent to Park and Ride and properties u/s Botley Road (2d_zsh_FAS_Defences_polyline.shp)
	E. Defence on Osney Ditch adjacent to Helen Road (2d_zsh_FAS_Defences_polyline.shp).
	F. Embankment upstream of Botley Road on right bank (2d_zsh_FAS_Defences_polyline.shp).

Example channels in reach A (left) and reach B (right)





Example channels in reach C (d/s of Botley Road)



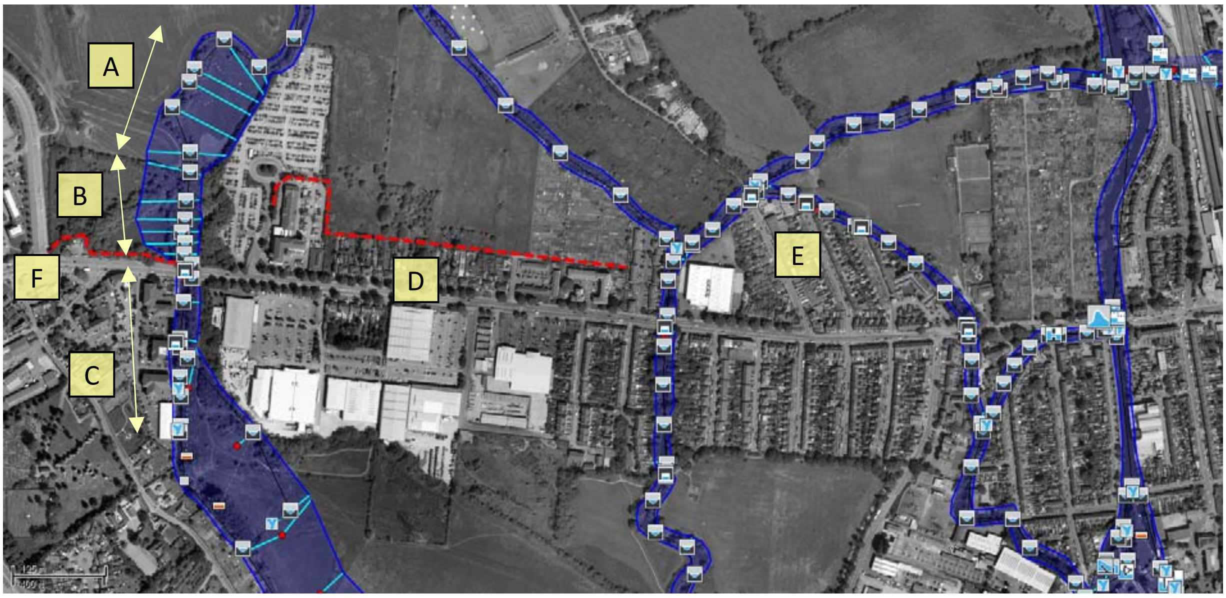
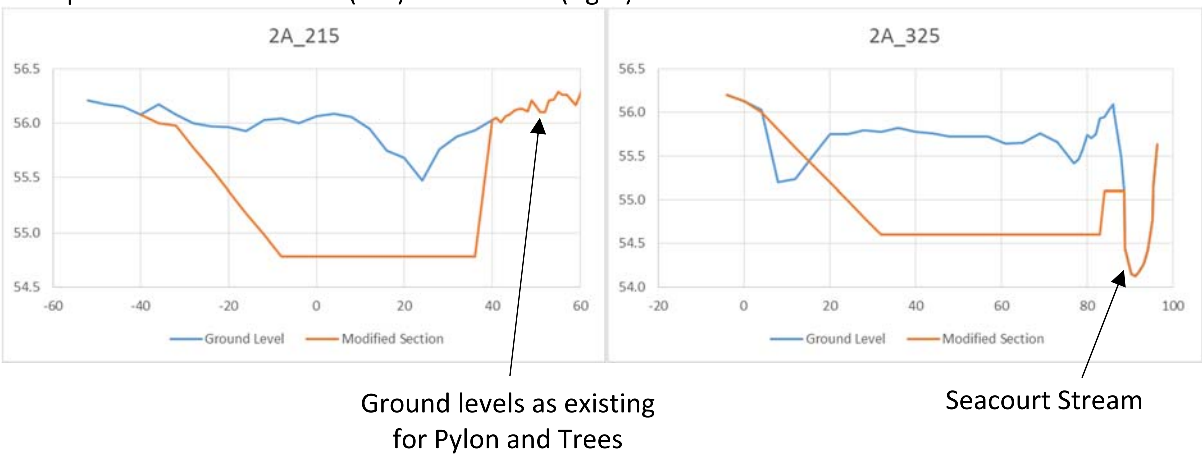


Table 26: Area 2 model schematisation

Area	Key features of the preferred option *(model nodes or 2D feature)*
2	**Botley Road to Willow Walk** A. New 1m deep scrape channel, bed level 55m to 54.8m (Nodes 2B_000 to 2B_215, area next to Seacourt Stream as existing ground levels for Pylon and trees. B. Seacourt Stream and new channel combined with low bank (potential access) between channels. (Nodes 2B_215d to 2B_530u). New channel bed level 54.8m to 54.26m, with shallow slope to existing ground levels on left bank. Seacourt Stream as existing. C. New channel separates from Seacourt stream with shallow slope to existing ground levels on left bank reducing to constrained section for new bridge at Willow Walk (bed levels 54.26m to 54m). D. Existing culverts under Willow Walk removed.

Example channels in reach A (left) and reach B (right)



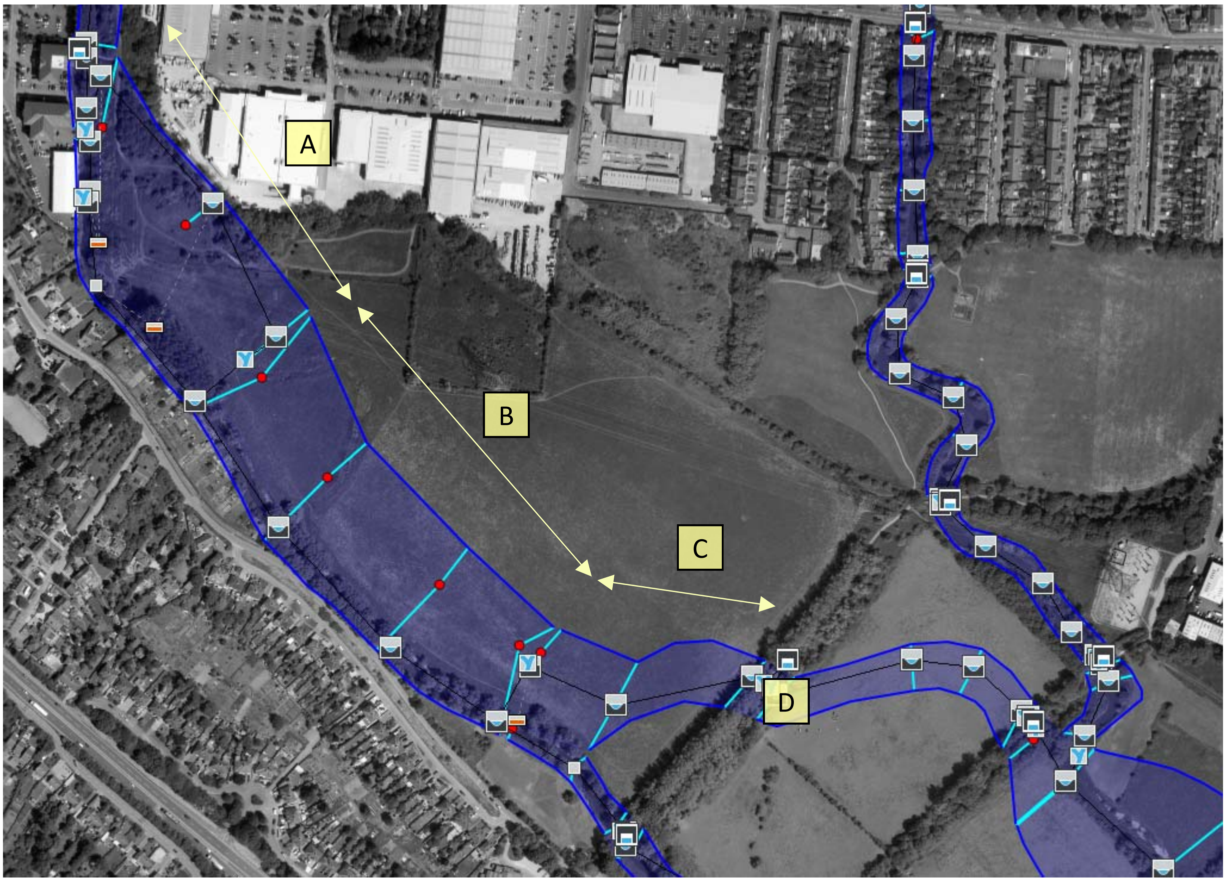
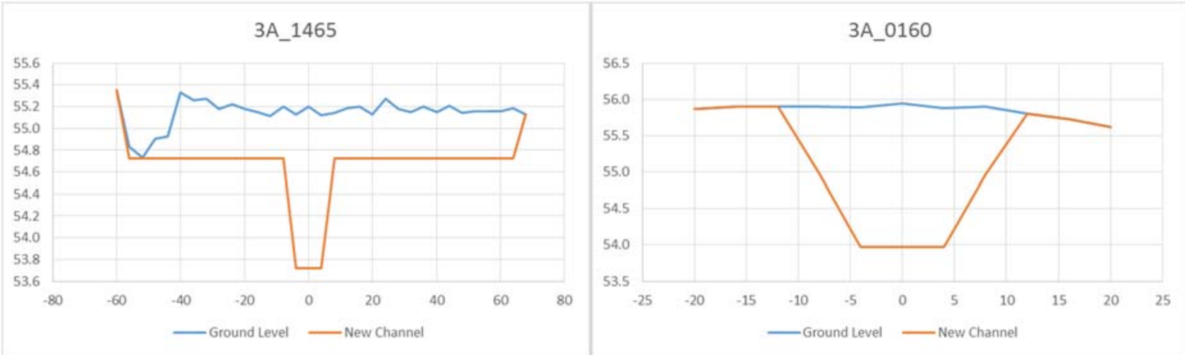


Table 27: Area 3 model schematisation

Area	Key features of the preferred option *(model nodes or 2D feature)*
3	**Willow Walk to Devil's Backbone** A. New constrained channel with new access bridge (3A_0201bu), with bed levels of 54.0m to 53.96m (Nodes 3A_0000 to 3A_0210). Typical channel depth of 1.8m. B. New 2-stage channel, with bed levels of 53.96m to 53.62m (Nodes 3A_0210 to 3A_1975). Typical channel depth of 0.5m on second stage with 1m deep channel (total depth 1.5m). C. New constrained channel with new access bridge at Devils Backbone (3A_2095bu), with bed levels of 53.62m to 53.60m (Nodes 3A_1975 to 3A_2095). Typical channel depth of 1.6m.

Example channels in reach A (left), reach B (right) and reach C (inset)



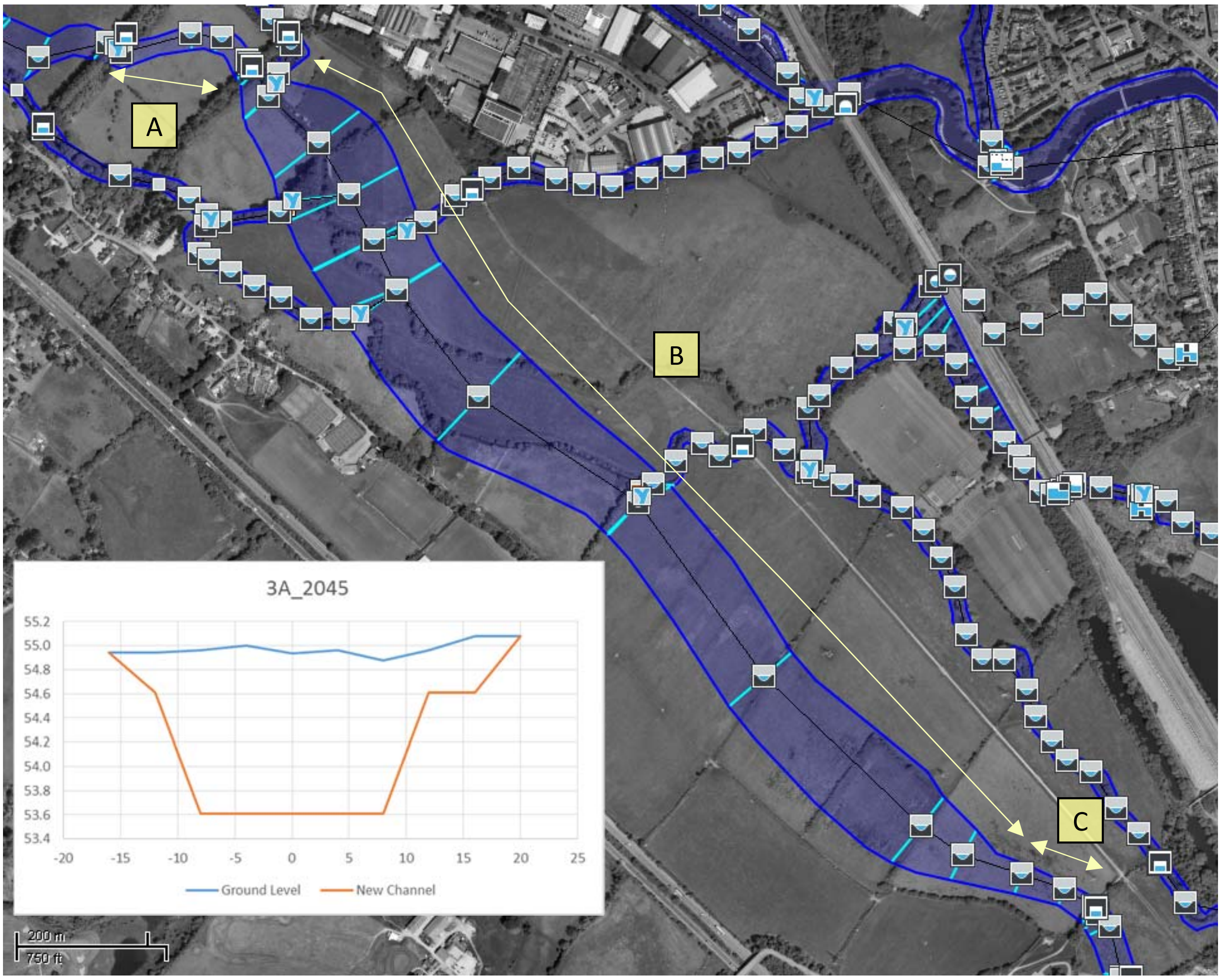


Table 28: Area 4 (Part 1) model schematisation

Area	Key features of the preferred option *(model nodes or 2D feature)*
4	**Devil's Backbone to Abingdon Road**
	A. New 2-stage channel Devil's Backbone to Railway with bed levels at 53.6m (Nodes 4A_000 to 4A_555) includes new access bridge (4A_105bu) and ford crossing (4A_455). Typical channel depth of 0.4m on second stage with 1m deep channel (total depth 1.4m).
	B. Widening of existing channels down to new channel, bed levels 53.6m to 53.5m. (This may be a 2 stage channel, which same capacity as the modelled widened channel).
	C. New constrained channel with bed levels of 53.5m to 52.7m, channel width increases from 25m to maximum of 55m around bend, total depth 1.5 – 2m.
	D. New triple culvert at Abingdon road, culvert size 7.2m x 1.95m, length 70m bed level 52.7m to 52.6m.
	E. Network Rail Culvert (Node Double_BoxUS - Double_BoxDS). Invert 54.125m as Network Rail model.
	F. Channel improvements Hinksey Stream from Network Rail Culvert to Mayweed Bridge, based on hard bed levels from survey (Nodes 46g.015C_us to 46g.001C). Towles Mill weir removed.
	G. Flow control to Redbridge ditch, modelled as bank level control, (node E-00706u).

Example channels in reach A (left), reach B (right) and reach C (inset)

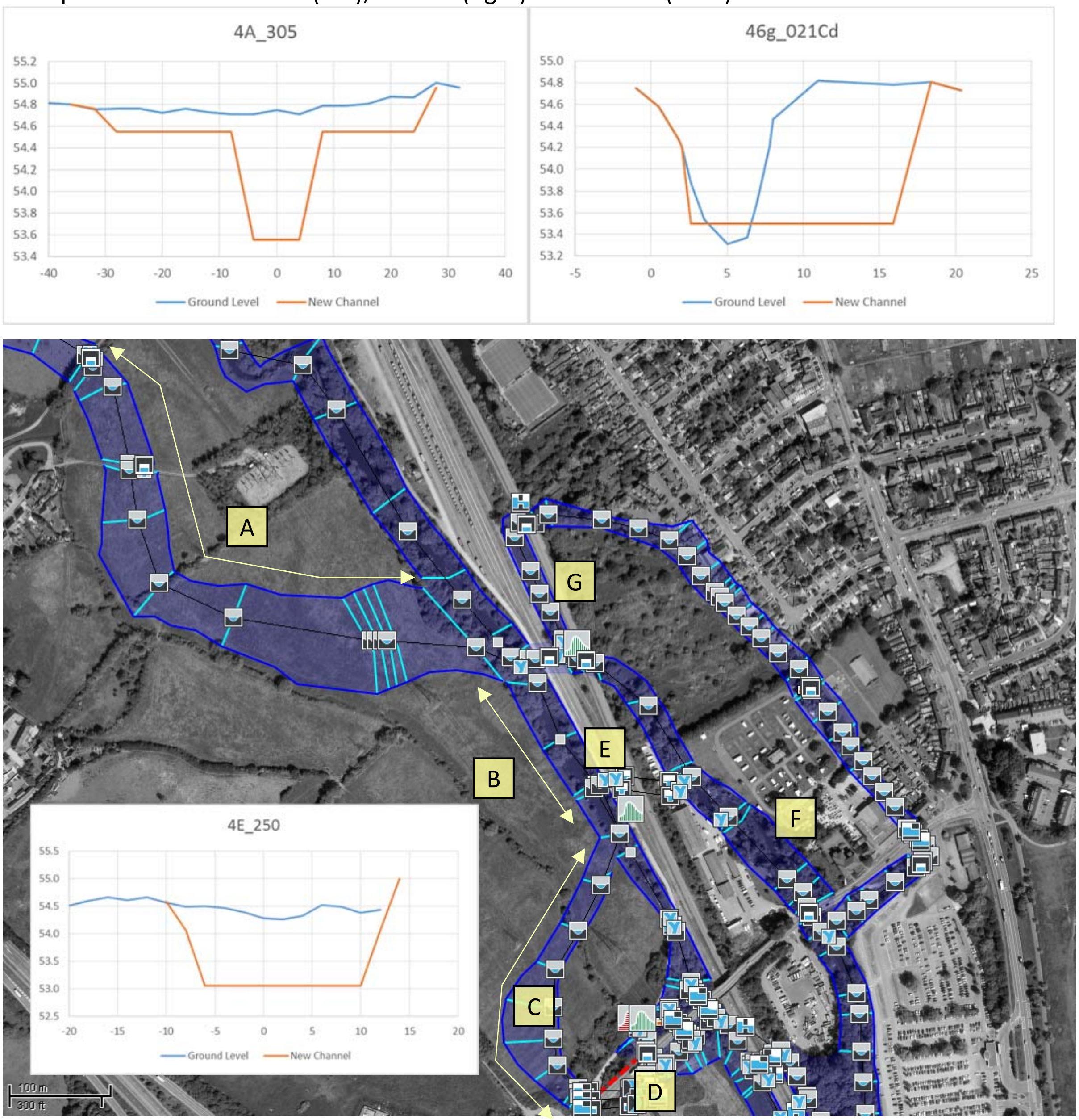
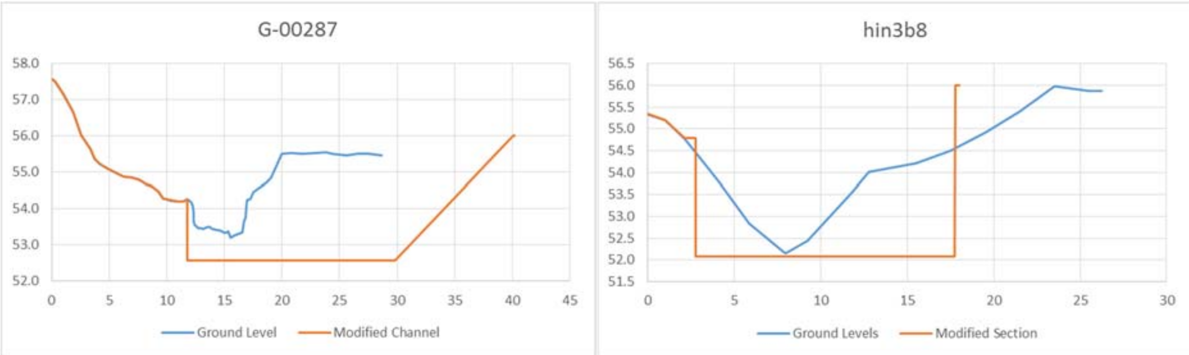


Table 29: Area 4 (Part 2) model schematisation

Area	**Key features of the preferred option** *(model nodes or 2D feature)*
4	**Devil's Backbone to Abingdon Road**
	A. Re-profiling of existing ditch from new Abingdon Road culvert to downstream of Strouds Bridge (4E_307 to hin3b2u) bed levels of 52.6m to 52.43m. Channel width varies from 15m a bed level with vertical sides on left bank and 1 in 2 slopes on right bank. Sections wider around bend.
	B. Re-profiling of existing ditch from downstream of Strouds Bridge to Mundays Bridge (hin3b2 to MU01.005) bed levels 53.43m to 53.5m. Channel size constrained between railway and Pylons and under A423.
	C. New channel and culvert under A423. Culvert 8m x 3.5m, currently 1D only, requires 2D links for 1000 year
	D. New channel and culvert under A423. Culvert 8m x 3.5m, currently 1D only, requires 2D links for 1000 year
	E. Channel improvement to Hinksey Stream from Mayweed to downstream side of Mundays Bridge, based on hard bed levels from survey (P-00327 to 46g.001C).
	F. Flood bund or headwall upstream of Abingdon Road culvert

Example channels in reach A (left), reach B (right) and reach E (inset)



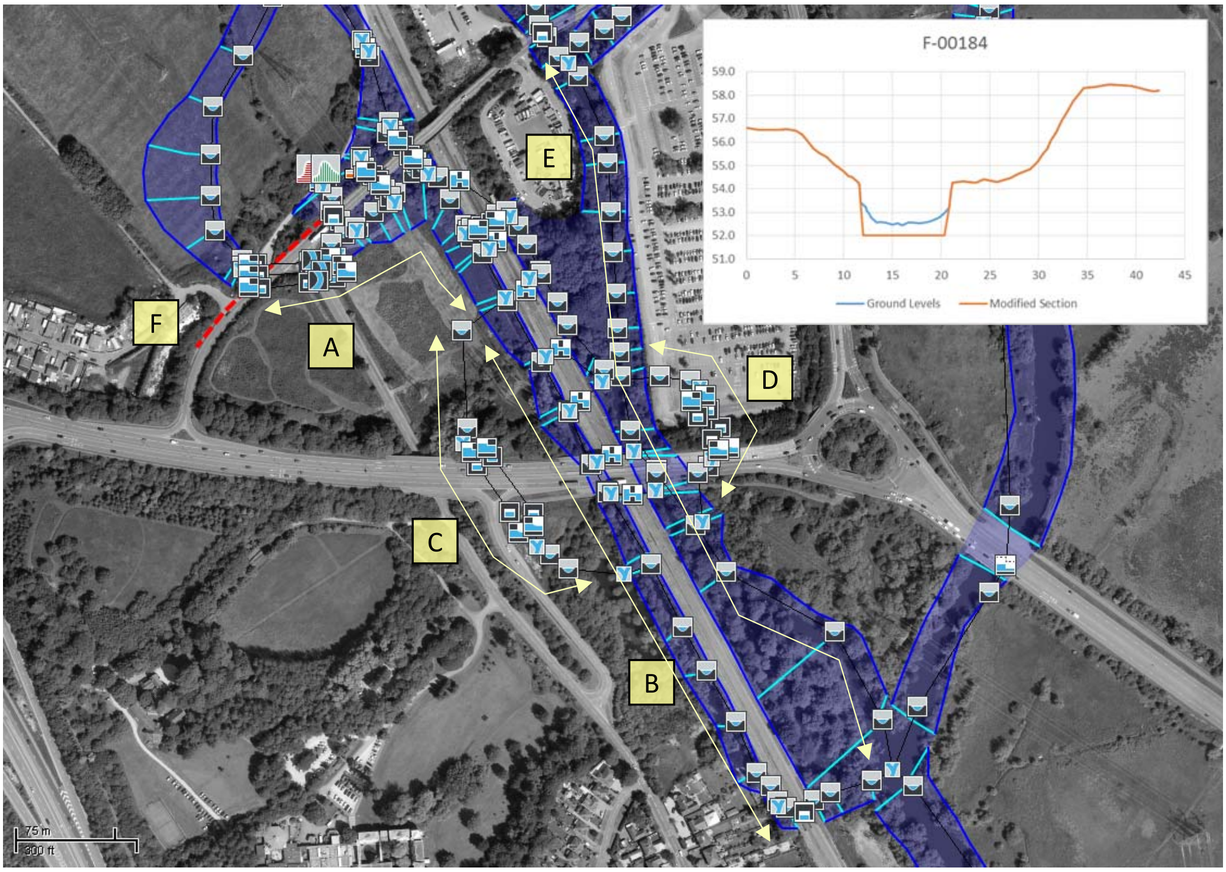


Table 30: Area 8 model schematisation

Area	Key features of the preferred option *(model nodes or 2D feature)*
8	**New Hinksey** A. Embankment from Hotel to Donnington Road (2d_zsh_FAS_Defences_polyline.shp) B. Park Embankment (2d_zsh_FAS_Defences_polyline.shp)

Table 31: Area 9 model schematisation

Area	Key features of the preferred option *(model nodes or 2D feature)*
9	**Weirs Mill Stream and Hinksey Stream to River Thames (Railway Bridge)** A. Potential improved channel conveyance of Weirs Mill Stream (Nodes 46h.070A to 46h.051A). Not modelled due to limited numbers of surveyed sections, which may not be representative of the current areas of reduced conveyance in the reach. B. Channel conveyance increased in Hinksey Stream (Nodes 46g.001D to 46g.001E).

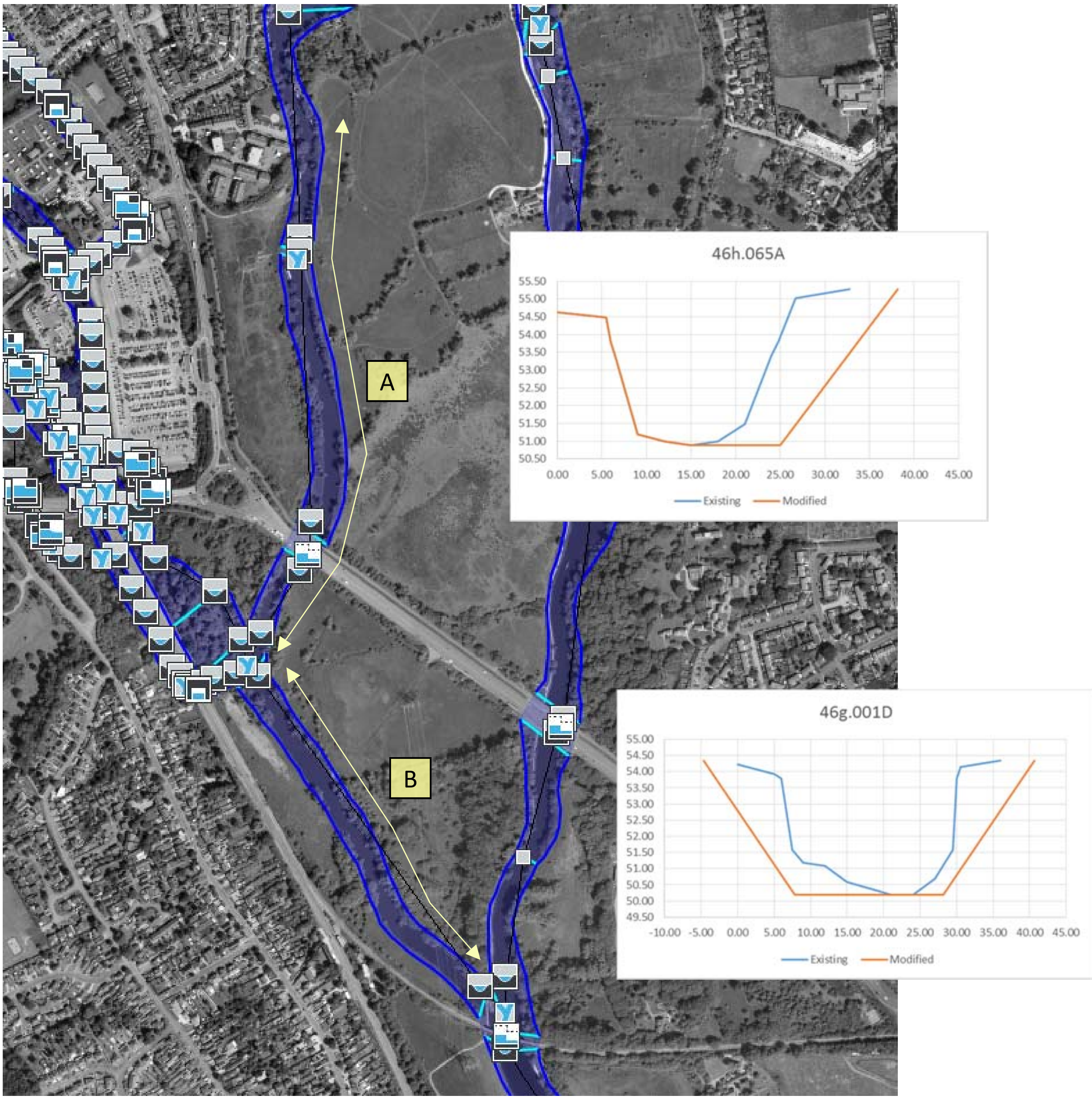


Table 32: Area 10 model schematisation

Area	Key features of the preferred option *(model nodes or 2D feature)*
10	**Eastwyke Ditch** A. Control structure approximately 100m east of the railway to restrict flow to the Thames (Node EW01.020fd). Modelled as flapped orifice to ensure flow is restricted when levels on the western side of the railway are higher. Bank levels increased between railway and structure to prevent bypassing (2d_zsh_banks_FAS_Hk_polyline/point).

7.4 Model Performance (Outline Design)

The model runs satisfactorily with minimal divergence for the outline design events. Figure 20 details the convergence plots produced as part of the 1D model outputs for the outline design.

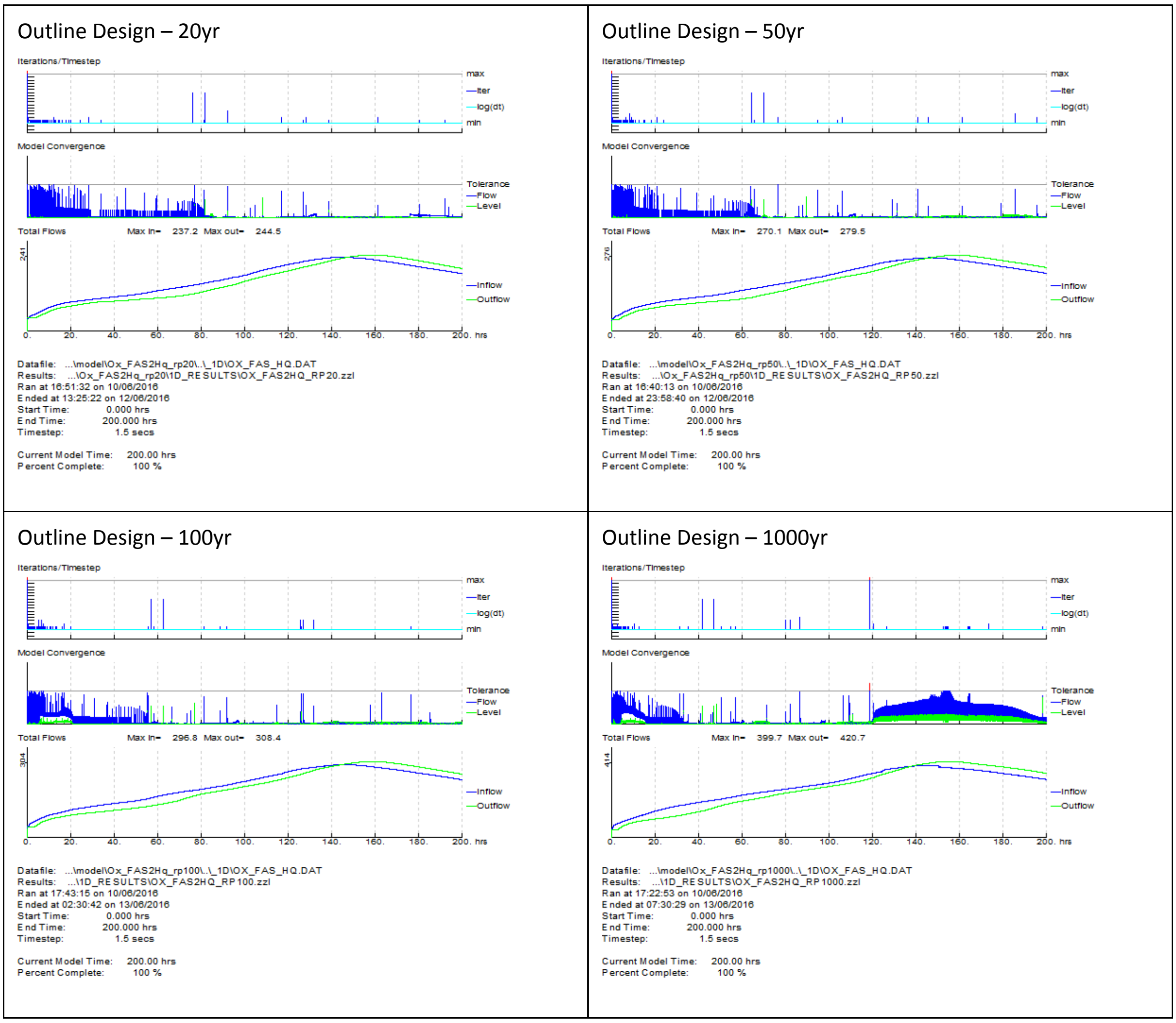


Figure 20: 1D convergence plots – Outline Design

A sample range of the 2D output of cumulative mass errors and dVol (smooth plots), with outputs from the 20, 50, 100 and 1000 year events are detailed in Figure 21. The cumulative mass errors are within +/- 1%.

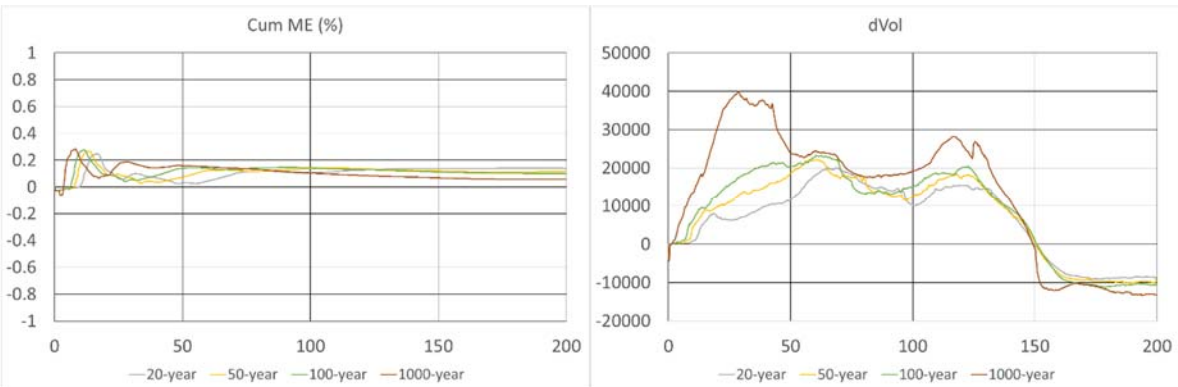


Figure 21: 2D Cumulative Mass Error and dVol (Outline Design)

7.5 Results

Peak water levels and flows are detailed in Table 33 for the 100 year event. Results for the 20, 50 and 1000 year are included in Appendix F.

Table 33: Peak water levels and flows – 100 year

ID	Node	Locations	Peak Water level (mAOD) and Differences (m)			Peak Flow (m^3/s) & Headloss (m) *	
			DM	Option	Diff	DM	Option
1	49.003U	Godstow Weir U/S	58.48	58.48	0.00	61.2	61.2
2	48.085	Godstow Weir D/S	58.08	58.05	-0.03	0.40	0.43
3	48.046	Thames at Castle Mill Stream	57.78	57.69	-0.09	101.0	104.2
4	48.021	Thames at Bulstake Stream	57.54	57.35	-0.19	59.5	61.7
5	47m.083B	Seacourt Stream D/S Thames offtake	59.72	59.72	0.00	8.7	8.7
6	47m.052B	Seacourt Stream A34	57.90	57.87	-0.04	69.3	69.2
7	47m.036B	Seacourt_Stream/Botley Stream	57.58	57.37	-0.21	13.6	17.7
8	SS-01391	Seacourt_Stream - Botley Rd U/S	57.52	57.22	-0.30	29.4	76.6
9	47m.28S	Seacourt_Stream - Botley Rd D/S	57.48	57.02	-0.46	0.04	0.20
10	47k.017	Bulstake Stream - Botley Road U/S	57.34	57.14	-0.20	63.7	51.5
11	BS01.047	Bulstake Stream - Botley Road D/S	57.26	57.09	-0.16	0.09	0.05
12	48.007	Thames - Osney US	57.12	56.91	-0.22	55.2	46.2
13	47f.006A	Castle Mill Stream	57.51	57.32	-0.19	16.4	13.9
14	47r.004	Osney Ditch - Botley Road U/S	57.48	57.26	-0.22	15.8	15.3
15	OD01.004	Osney Ditch - Botley Road D/S	57.25	57.03	-0.22	0.23	0.23
16	47.102	Thames - Osney DS	56.40	56.27	-0.13	122.1	105.7
17	HS2.001	Devils Backbone	56.48	56.31	-0.16	19.1	18.2
18	E-00690b	Hinksey Stream - Railway Bridges U/S	56.43	56.20	-0.23	24.7	20.1
19	E-00676d	Hinksey Stream - Railway Bridges D/S	56.35	56.12	-0.22	0.08	0.08
20	M-00158	Redbridge Stream - Abingdon Road U/S	56.17	55.66	-0.50	4.8	2.9
21	M-00133	Redbridge Stream - Abingdon Road D/S	55.94	55.58	-0.36	0.22	0.09
22	46g.012C	Mayweed Bridge - Abingdon Road U/S	56.28	56.06	-0.21	28.0	31.3
23	P-00327	Mayweed Bridge - Abingdon Road D/S	55.92	55.59	-0.32	0.36	0.47
24	G-00320b	Hinksey Drain - Abingdon Road U/S	56.38	56.13	-0.26	21.5	18.6
25	G-00320	Hinksey Drain - Abingdon Road D/S	56.09	55.91	-0.19	0.29	0.22
26	Q-00177a	Strouds Bridge U/S	55.97	55.83	-0.13	7.4	14.0
27	Q-00156	Strouds Bridge D/S	55.97	55.66	-0.31	0.00	0.17
28	MU01.005	Mundays Bridge U/S	55.44	55.40	-0.05	26.0	61.0
29	46g.001D	Mundays Bridge D/S	55.40	55.29	-0.10	0.05	0.11
30	46g.004C	Hinksey Stream A423 Bypass D/S	55.41	55.36	-0.06	50.3	51.0
31	hin3b6a	Hinksey ditch A423 Bypass D/S	55.58	55.51	-0.07	22.2	61.0
32	46h.070A	Weirs Mill Stream - Donnington Br D/S	55.57	55.43	-0.14	89.8	85.4
33	46h.065A	Weirs Mill Stream	55.51	55.39	-0.12	59.5	50.0
34	EW01.008	Eastwkye Ditch A4144	56.09	56.00	-0.10	6.8	0.3
35	EW01.023	Eastwkye Ditch - Railway Culvert	56.43	56.37	-0.06	15.2	0.7
36	TH47_003	Thames - Iffley Lock U/S	55.73	55.65	-0.08	0.70	0.73
37	46.038	Thames - Iffley Lock D/S	55.15	55.15	0.00	284.9	284.3
38	46.03	Thames - Railway	54.91	54.91	0.00	238.8	237.9
39	45.166	Thames - Rose Isle	54.15	54.15	-0.01	0.76	0.76
40	46.002	Thames - Sandford Weir U/S	54.55	54.55	0.00	98.6	98.5
41	45.179	Thames - Sandford Weir D/S	54.33	54.32	-0.01	0.23	0.23
42	45.164	Thames - Sandford Lock D/S	54.15	54.15	-0.01	226.9	226.3
43	45.128	Thames Outflow	53.83	53.83	-0.01	292.2	291.1
44	Ab_culu	New Abingdon Road Channel		56.11			51.6
45	L-00683d	Redbridge Brook D/S Railway	56.24	55.72	-0.52	4.2	2.6
46	CH.014	Cherwell Oxford Gauge	56.23	56.18	-0.05	44.4	44.6

* Peak 1D flow indented left, structure head loss indented right

Comparison of the flood extents for the 100 year event are detailed in Figure 22 which shows the impact of the FAS at a high level. Further comparison is made for the 100 year at Botley Road (Figure 23) and New Hinksey (Figure 24) which detail the new raised defences proposed in the FAS.

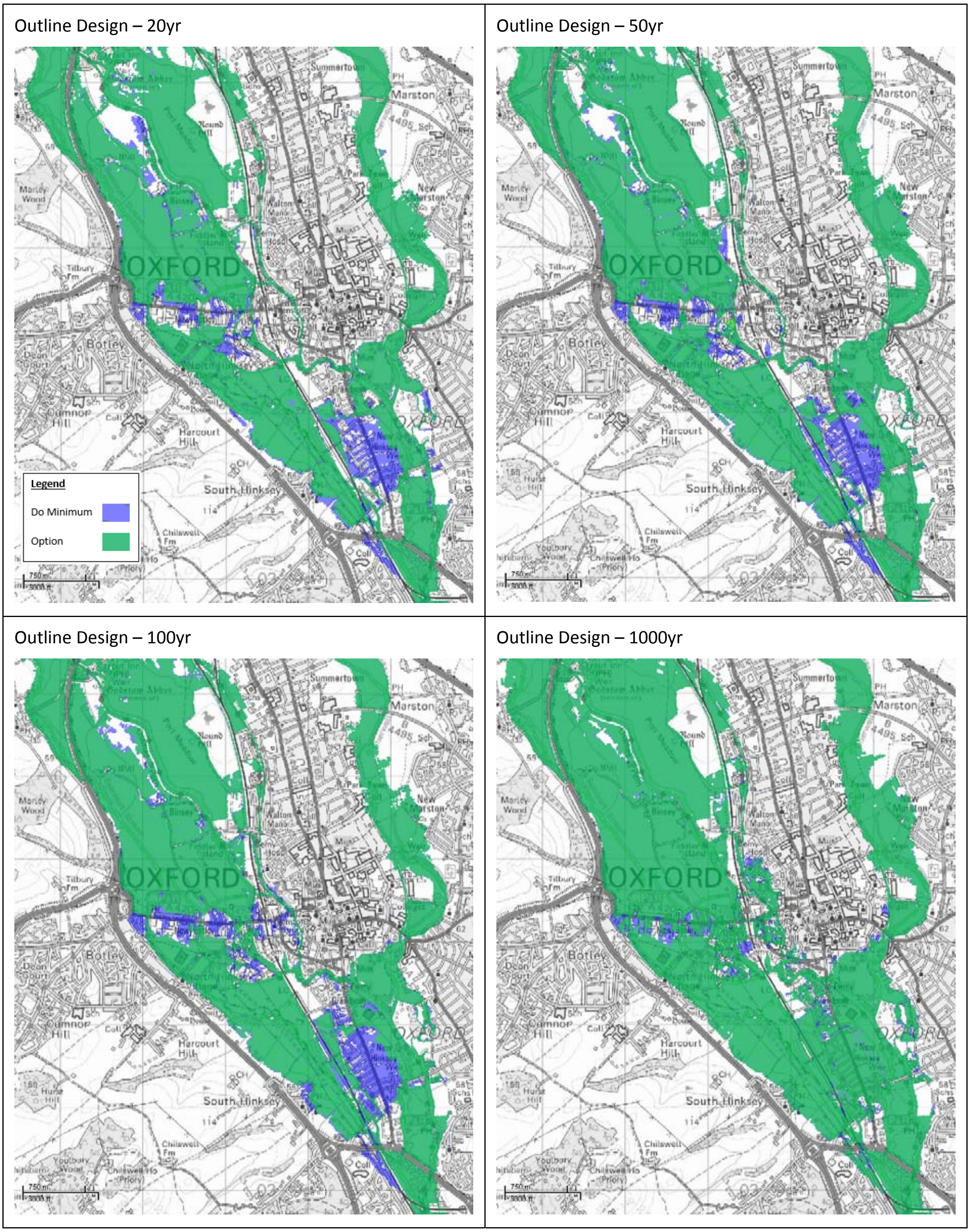


Figure 22: Flood extent comparison – 20, 50, 100 and 1000 year

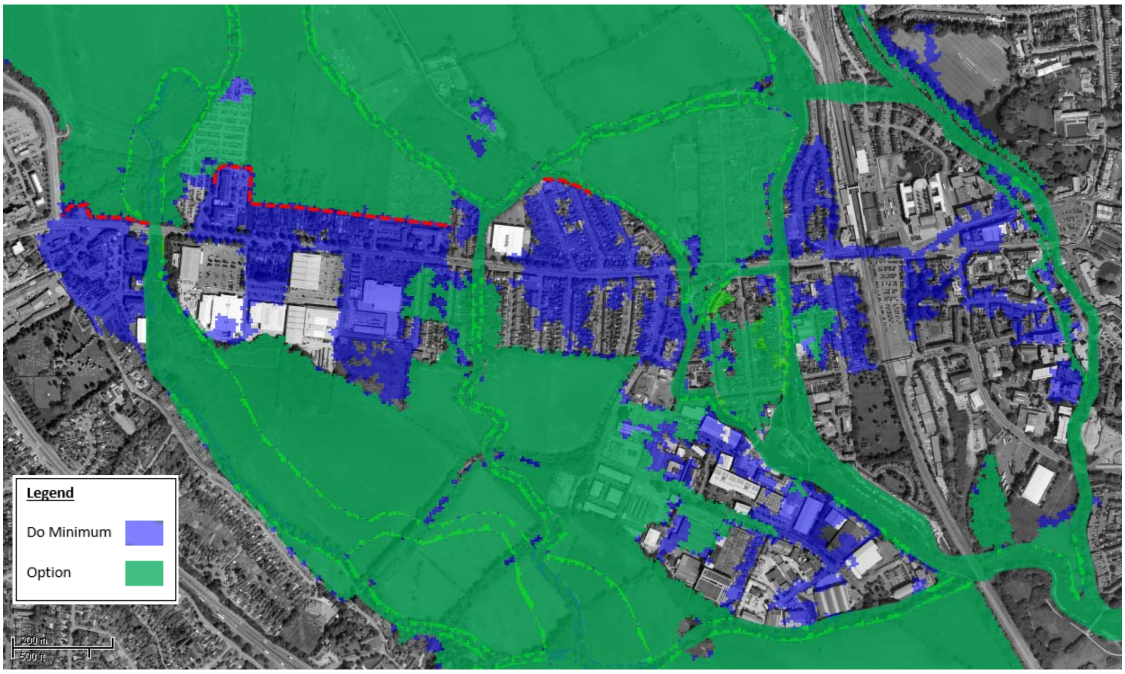


Figure 23: Flood extent comparison – 100 year Botley Road
© Bluesky International Ltd/Getmapping PLC

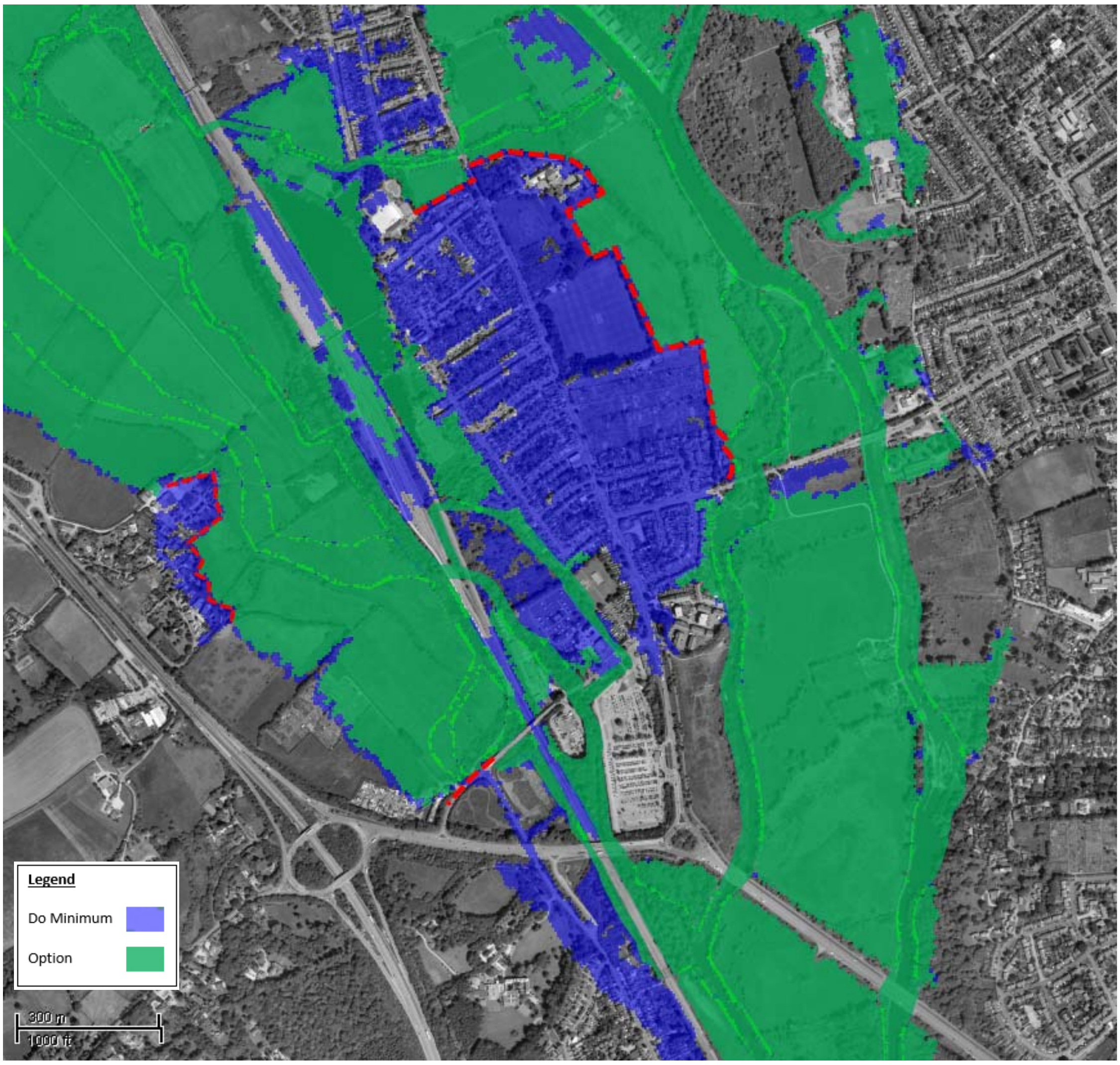


Figure 24: Flood extent comparison – 100 year New Hinksey
© Bluesky International Ltd/Getmapping PLC

7.6 Comparison of flows at Sandford

Comparison of the model outflow for do minimum and the preferred option are detailed in Figure 25 (20, 50, 100 and 1000 year). The modelling predicts that the scheme would result in a small reduction in peak flow (apart from 2 and 1000 year, where there is a slight increase) with higher flows in the rising limb of the hydrograph due to increased conveyance of the scheme. Peak flows for the full range of design events are presented in Table 34.

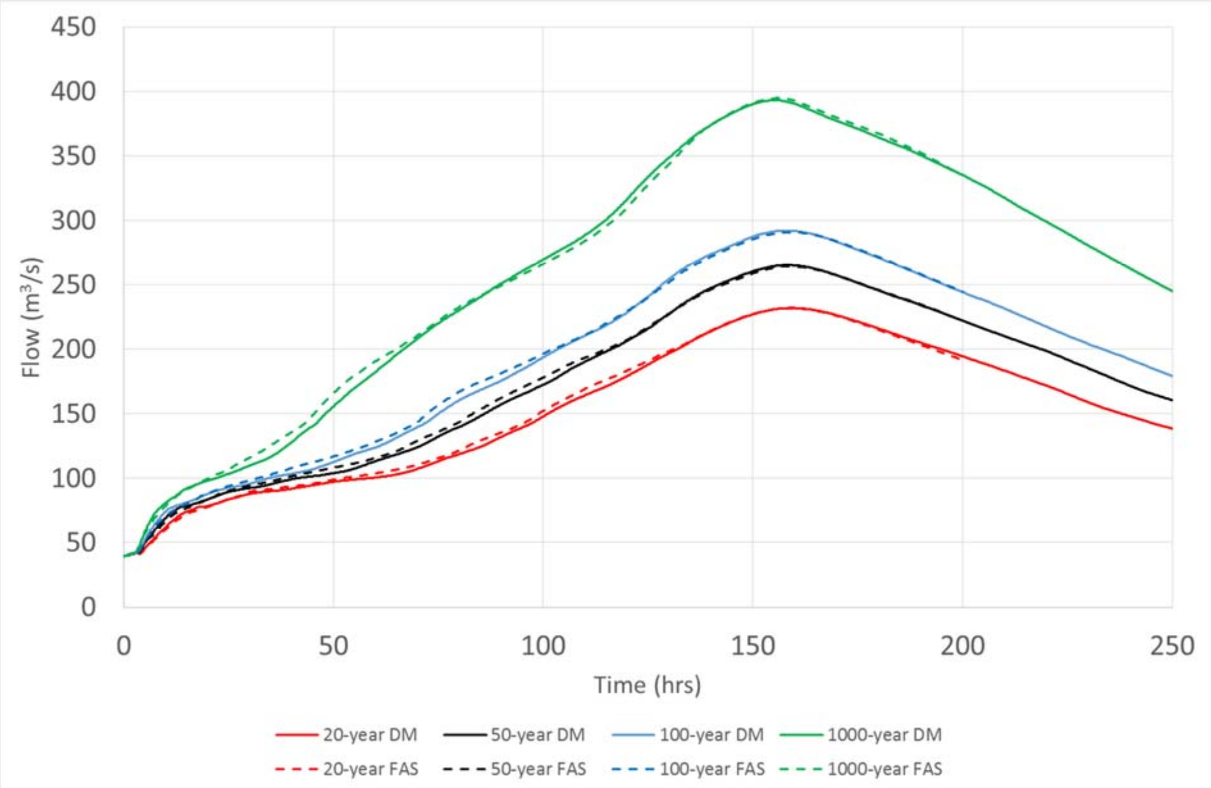


Figure 25: Comparison of flows at Sandford

Table 34: Peak flow comparison at Sandford

Location (model node)	2	5	10	20	50	75	100	200	1000
Do Minimum (m^3/s)	140.39	180.44	208.20	231.93	265.27	280.79	292.19	320.01	393.22
Outline Design (m^3/s)	140.71	178.45	207.50	231.77	264.30	280.11	291.00	318.46	394.85
Difference (m^3/s)	0.32	-2.00	-0.70	-0.16	-0.97	-0.68	-1.18	-1.54	1.63
Difference (%)	0.23%	-1.11%	-0.34%	-0.07%	-0.37%	-0.24%	-0.41%	-0.48%	0.42%

7.7 Climate change simulations

7.7.1 Overview of relevant climate change guidance

There are two current climate change documents that this project needs to consider and refer to. These are:

1. Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities - updated 13 April 2016 (original version: September 2011)
2. Flood risk assessments: climate change allowances - published 19 February 2016

The two climate change documents have different uses. The first should be used when working for Risk Management Authorities (Environment Agency, lead local flood authorities, etc) to develop FCERM projects for them. This includes developing Strategic Outline Cases (SOCs), Outline Business Cases (OBCs) and Full Business Cases (FBCs). The second should be used when preparing deliverables which are used by the Environment Agency to provide advice on flood risk assessments, strategic flood risk assessments or similar. Also, it should be used when preparing such documents.

The key difference between the two documents is that the first focuses on the **central 'change factor'** together with understanding the sensitivity of the proposed solution to higher and lower estimates; whilst the second is more prescriptive and precautionary and gives more specific guidance on which factors to use (depending upon the nature of the development and the flood zone within which that development is proposed).

As the focus of the flood modelling reported herein has been in support of developing the OBC, the first climate change document provides the key reference at this stage. As the flood risk assessment is developed in support of the planning application (during the detailed design phase), the second climate change document will be of greater interest, particularly consideration of the High++ scenario. Potential 'offsite impacts' will also require further consideration and scrutiny under different climate change scenarios, including the potential for downstream impacts.

7.7.2 Climate change simulations undertaken in support of the OBC

As noted in section 6.4.1, the do minimum and do nothing simulations did not need to consider climate change. Instead, for future epochs, the economic assessment used model results from 'year 0' and assigned new return periods, adopting current guidance[5] to inform this process. So for example, in estimating annual average damages the 'year 0' 1 in 100 return period is assigned a 1 in 22 year return period by year 50.

When considering the 'with option' scenarios, whilst the same approach to shifting return periods from year 0 was applied to calculate damages, a set of additional runs with the FAS scheme were required to provide property counts for use in the partnership funding calculator. The additional 'with scheme' scenarios in year 50 were run for all return periods, with both a 15% and 25% increase in flow.

Finally, a set of 12 additional simulations were undertaken, to provide additional information for the Environment Agency's flood map, and for use in preliminary planning consent consultations (i.e. ahead of the formal planning application, which will be made during the detailed design stage). These simulations scaled the model inflows by the percentages listed against each scenario in Table 35 below.

Scenario	'Do minimum' peak flow at Sandford (m3/s)	'With FAS' peak flow at Sandford (m3/s)
1 in 20 + 25%	287	285
1 in 20 + 35%	308	307
1 in 20 + 70%	381	383
1 in 100 + 25%	353	354
1 in 100 + 35%	386	388
1 in 100 + 70%	477	478

Table 35: Additional modelling scenarios undertaken and mapped for the Environment Agency

[5] Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities, Environment Agency, 2016

7.7.3 Implementation of climate change in assessing benefits

Climate change was incorporated as specified in the Current Guidance[5]. Estimates for the different scenarios for the Thames Catchment are reported in Table 1Table 36 below.

Year	Climate Change Estimate (percentile)			
	Lower (10th)	**Central (50th)**	**Higher Central (70th)**	**Upper (90th)**
Year 0 (2016)	0	0	0	0
2025 (2020s)	-5	10	15	25
2040 (2050s)	0	15	25	35
2070 (2080s)	5	25	35	70

*expressed as increase in flow from 2016 baseline flow

Table 36: Climate change estimates and scenarios

The Central (50th percentile) scenario has been used to drive economic decision making using the FCRM-AG decision rule. The remaining percentiles have been used as sensitivity tests, summarised as follows:

- Lower (10%ile) Climate Change Estimate applied to Future Epoch Flows
- Higher Central (70%ile) Climate Change Estimate applied to Future Epoch Flows
- Upper (90%ile) Climate Change Estimate applied to Future Epoch Flows

It is worth noting that the H++ scenario has not been considered at this stage, as this is not necessary for the development of the outline business case. For reference, the H++ scenario presents the following climate change estimates for the Thames (in comparison to Table 36 above).

- 2020s = 25%
- 2050s = 40%
- 2080s = 80%

Low Flow modelling (Q_{95})

The Do Minimum and Outline Design models have been schematised to run under low flow conditions.

8.1 95% Exceedance flows (Q_{95})

The model has been run with constant flows, based on the Q95 flows from gauging stations at Farmoor (Thames), Cassington (Evenlode), Enslow (Cherwell) and Islip (Ray). The flows have been taken from National River Flow Archive as detailed in Table 37.

Table 37: Q95 flows

Station	Station Number	Watercourse	Q95 (m^3/s)
Eynsham	39008	Thames	1.150
Cassington	39034	Evenlode	0.629
Total Thames			**1.779**
Enslow	39021	Cherwell	0.657
Islip	39140	Ray	0.150
Total Cherwell			**0.807**

Source: National River Flow Archive, http://nrfa.ceh.ac.uk/

8.2 Model schematisation for low flow

The flood modeller 1D hydraulic model, which represents current conditions (do minimum) developed for the Oxford FAS study has been used as the starting model for the low flow modelling. To enable a stable and successful simulation for the low flows, the model schematisation had to be modified. This required closing structures, removing structures and adding small localised slots (0.01m wide) and weirs where water levels were at or below the bed level of the cross sections.

Checks were also made against the operational structure requirements from the Low Flow Operating Procedures documents, which are summarised in Table 38 and a record of the changes to model schematisation are detailed in Table 39.

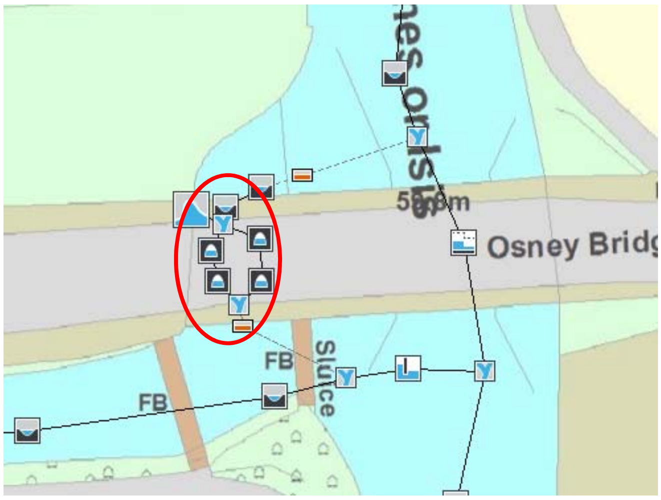
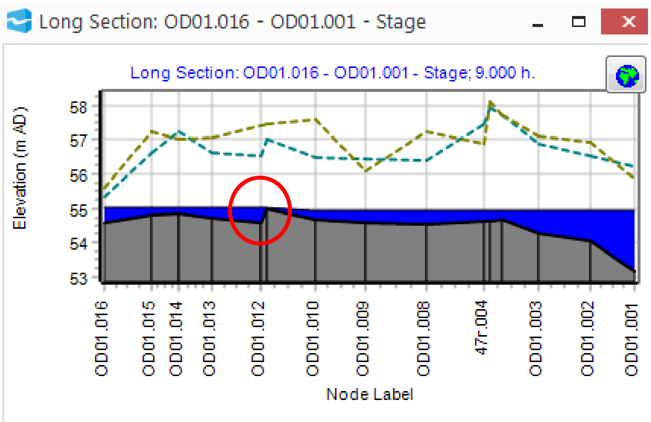
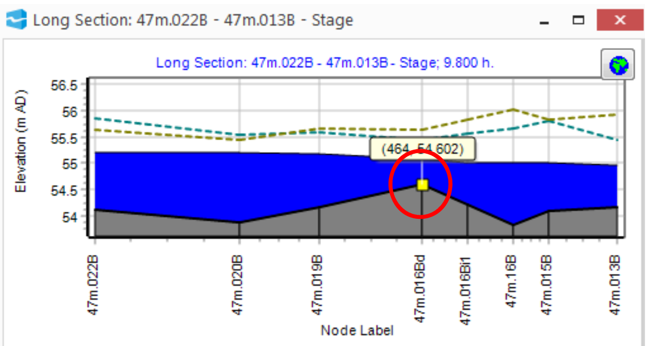
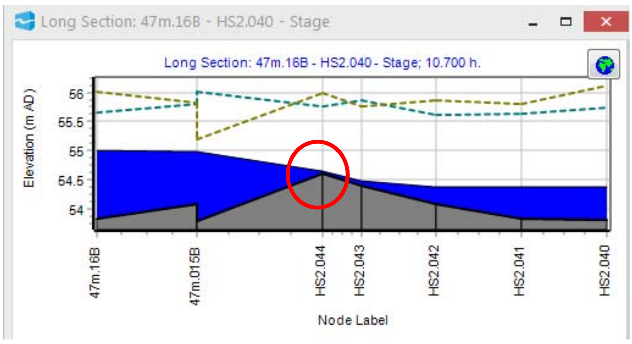
The same modifications applied to the current conditions models have been added to the outline design model.

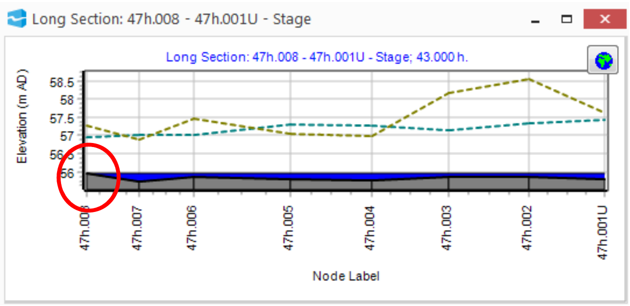
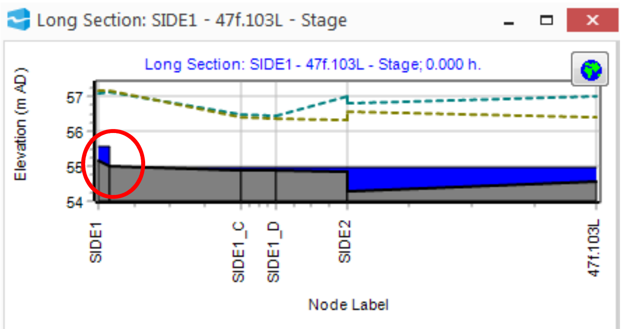
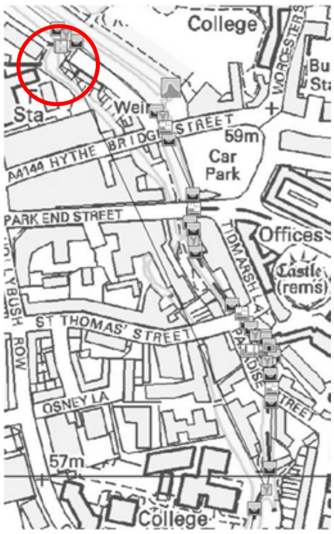
Table 38: Low Flow Operating Procedures document

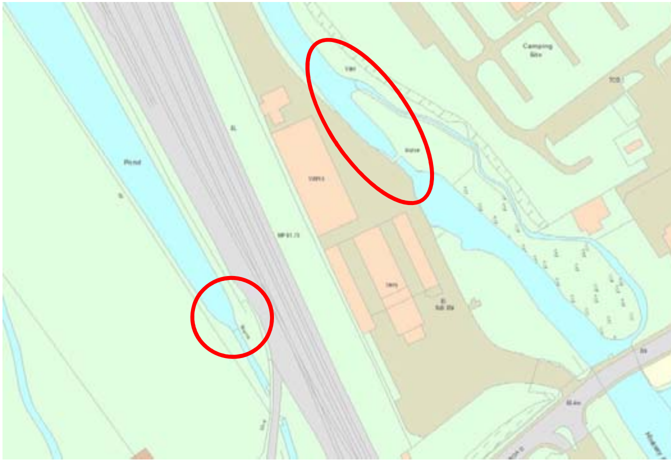
Reach	Structure	Position in Low Flows	Position in Very Low Flows	Model Comment
King's	Kings Main Weir	Closed and Sealed	Closed and Sealed	Main weirs closed
King's	Kings Island bypass channel	Notched board in place	Closed	Model includes weir 4m wide at 58.66mAOD, not details of boards
King's	Seacourt Overfall	One summer board	Two summer boards	47m.084B, lowest weir level 58.63mAOD raised to 58.78 to represent board
King's	Wolvercote Mill Radials	Closed and sealed	Closed and sealed	Closed
King's	Wolvercote Mill Sluices	Both open 20mm (3/4")	Closed	Set 20mm, model has each sluice 3.5m wide
King's	Kings Lock	Open some restrictions on lockage	Possible further restrictions in Navigation	Lock not modelled
King's	Duke Cut Lock	Open some restrictions on lockage	Possible further restrictions in Navigation	Lock not modelled
Osney	Osney Radial Gate	Closed and sealed	Closed and sealed	Tilting gate raised
Osney	Osney Hand Radials	Closed and sealed	Closed and Sealed	Closed
Osney	Osney Mill Hydropower Schemes	Closed and sealed/not operating	Closed and sealed/not operating	Not modelled
Osney	Osney Bridge Buck	Reduced or shut	Shut (Ensure bridge weir is running with central board not in position)	Closed, only opened during flood conditions
Osney	Abbey Sluice	Part open	Closed	47z.BGAU, replaced with sluice for part open
Osney	Castle Mill Main Gate	Closed	Closed	47f.BGAU Assume now Flap Gate – Closed in model
Osney	Castle Mill Lasher Weir	One board inserted	Closed	Unsure of weir location within model?
Osney	Park End Penstock	Closed	Closed	d/s of Pacey's Bridge, assume to be represented in model in nodes 47f.BGBU and 47f.BGCD – set closed
Osney	Osney Fish Pass	Open	Partially or fully closed	Weir level assumed set at 56.507m
Osney	Osney Lock	Open	Possible restrictions	Lock not modelled

Appendix to the Waterway Drought Plan (Revised 2015) - Low Flow Operating Procedures

Table 39: Schematisation changes for low flow modelling

<table>
<tr><th>No.</th><th>Description</th><th>Additional Information</th></tr>
<tr><td>1</td><td>Moveable structures closed at all lock complex's</td><td>Model as per Table 38, other main weir at locks (Godstow, Iffley and Sandford) closed.</td></tr>
<tr><td>2</td><td>2 Arch culverts under Osney Bridge removed downstream of the side weir (control at low flows)</td><td>
</td></tr>
<tr><td>3</td><td>Osney ditch, section OD01.11, bridge unit replaced with spill as channel would go dry, u/s and d/s sections bed level modified</td><td>
</td></tr>
<tr><td>4</td><td>Willow Walk Bridge removed (WILLOWU), crashes model, replaced with junction. Section 47m.016Bd spill added using cross section, d/s interpolate used as d/s cross section of spill to maintain node names</td><td>
</td></tr>
<tr><td>5</td><td>Spill using section HS2.044 added between nodes HS2.044 and HS2.043, bed levels of u/s, d/s sections modified (represents a ford)</td><td>
</td></tr>
</table>

No.	Description	Additional Information
6	47h.003, bed level lowered by 0.15m to 55.85 (Fishers Island Stream), Slot added to all sections in the reach (down to 55.11mAOD) Bernoulli 47h.001U removed and downstream end. Spill added to start of the reach using section 47h.008	
7	Side channel at Castle Mill Weir, slot added in sections SIDE1 – SIDE 2	
8	Sandford Side Weir (46d.SSU), downstream link added to 1D model (previously HTBDY for 2D link)	
9	Abbey Sluice Buck Gate (47z.BGAU), downstream link added to 1D model (previously HTBDY for 2D link) Orifice unit replaced with sluice unit to model partial closed condition.	
10	Bulstake Stream Tumbling Bay Weir (BS01.071)	Model has crest of 56.41m from survey 8162 dated 2005. Thames water reprt states level of 56.49m and topo survey 4966, dated 1999 has crest levels of 56.47m Crest levels have been raised, looks like survey 8162 takes lower crest on slope of weir (different approx 6cm)

No.	Description	Additional Information
11	Towles Mill Weir and Sluice at the end of the pond The model has assumed that Q95 low flows do not flow via the sluice at Towles Mill and instead flow via the pond as the preferred flow route. The model has been run tested with a larger flow which predicts similar levels at surveyed at the Cold Harbour railway bridge on the 11 May 2010. The same model schematisation has been used for Q95. For detailed design purposes survey of the Mill Weir, Sluice and the sluice on the pond will be requested.	

8.3 Low Flow control structures for outline design

4 control structures will be required to maintain water levels and direct low flows to the preferred channels, the locations of the structures are detailed in Figure 26

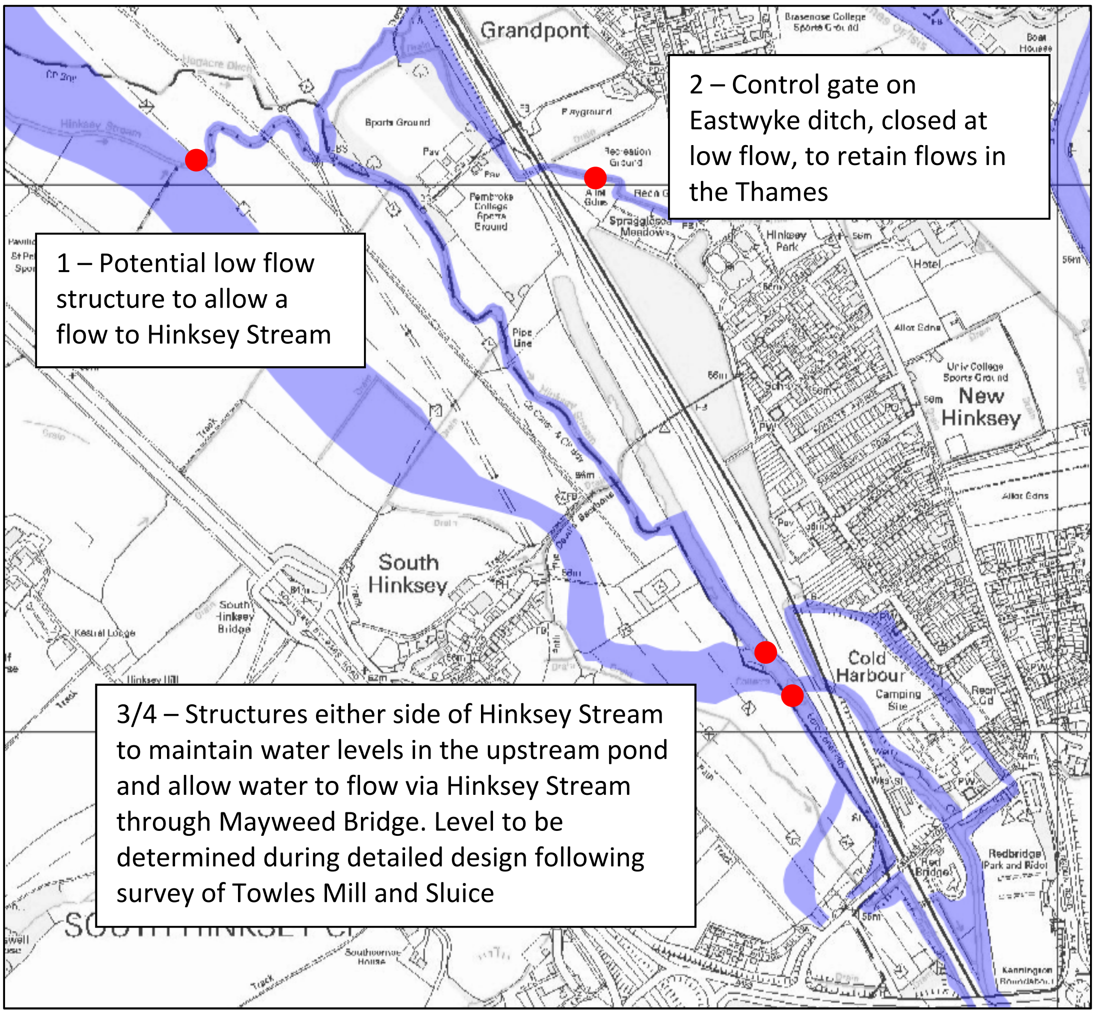


Figure 26: Low flow structure locations

8.4 Low Flow Results

Table 40 presents the flows and water levels predicted by the model for the Do Minimum and FAS outline design for the Q95 scenario at various locations within the model. Osney Ditch and Redbridge Stream channel have no flow and flow in the Hagacre and Eastwyke ditch is flowing in a westerly direction.

Figure 27 takes a flow diagram from the Thames Water/Atkins study, detailing the Q95 flow split in the Oxford watercourses based on the flow at Eynsham. The figure has been annotated by 'Do Minimum' model flow splits (green textbox). The model predicts the same flow splits as the Thames Water/Atkins study for flows in the Thames and Seacourt Stream. The model predicts slightly more flow in the Castle Mill Stream and less in Osney Stream with the flow remaining is the Thames passing through Osney Mill. There are no survey details to confirm the model schematisation of the mill structures are they not mentioned in the Low Flow Operating Procedures documents. However, the flows in the Bulstake and Osney Stream both return to Thames downstream of the mill.

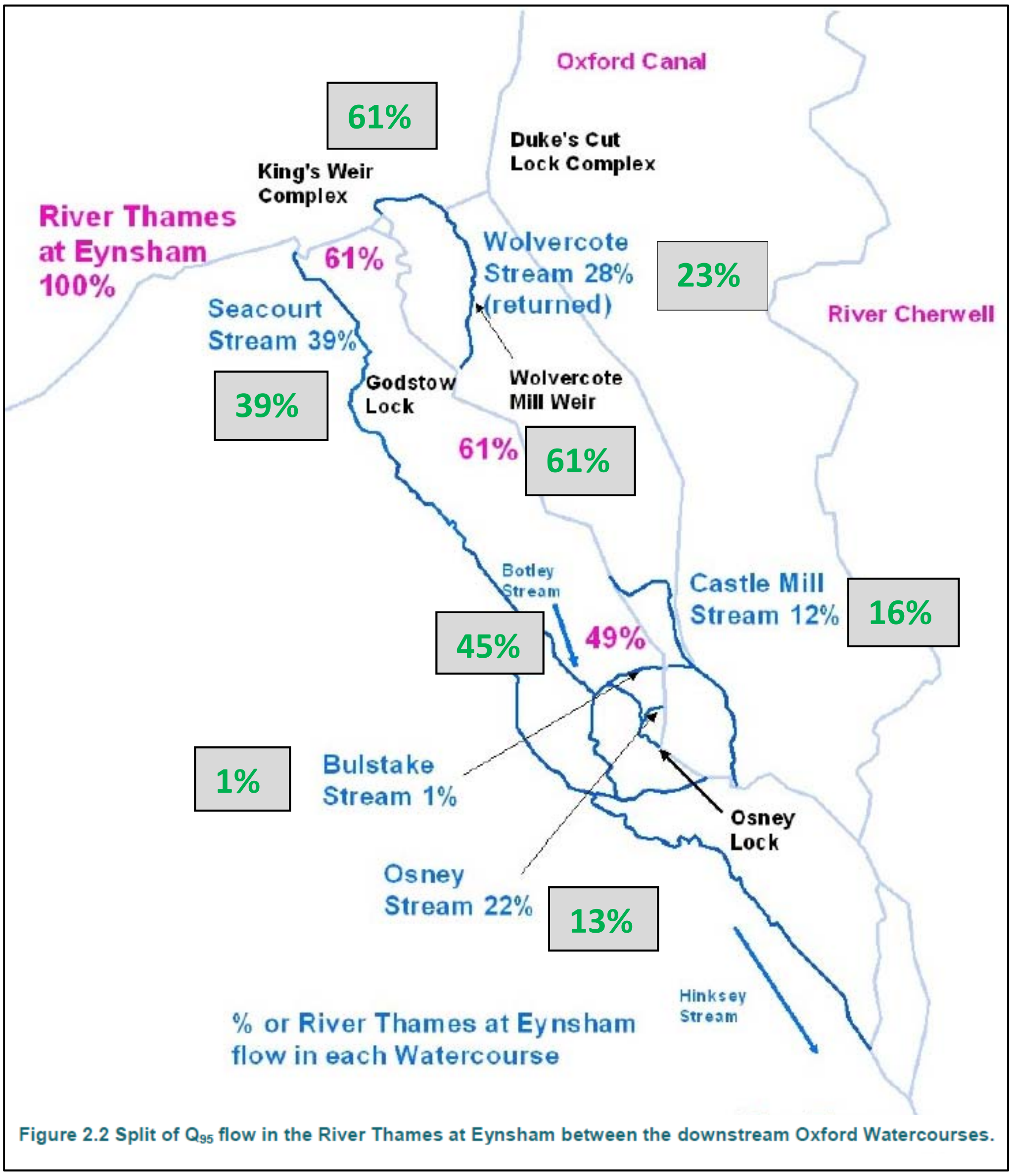


Figure 27: Q95 Baseline (Do Minimum) flow splits

Source: Thames Water document 'Oxford Watercourses – Summary Report and Options Appraisal, 11th September 2014, Atkins'

Table 40: Modelled Q95 flows and levels

Location	Node	Flow (m^3/s)			Water Level (mAOD)		
		Do Min	FAS	Diff	Do Min	FAS	Diff (m)
U/S Seacourt Weir	47m.084B	0.70	0.70	0.00	58.91	58.91	0.00
Seacourt A34 Bypass	47m.052B	0.70	0.70	0.00	55.35	55.34	-0.01
Seacourt U/S Botley Stream	47m.036B	0.70	0.70	0.00	55.09	55.06	-0.02
Seacourt Botley Road	SS-01391	0.30	0.33	0.03	55.03	55.02	-0.02
U/S Kings Weir	50.008	1.08	1.08	0.00	58.91	58.91	0.00
D/S Kings Weir	49.050	0.67	0.67	0.00	58.25	58.25	0.00
U/S Godstow Weir	49.003U	0.59	0.59	0.00	58.25	58.25	0.00
D/S Godstow Weir	48.085	1.10	1.10	0.00	56.48	56.48	0.00
U/S Osney Weir	48.007	0.57	0.57	0.00	56.48	56.48	0.00
Castle Mill Stream	47f.001A	0.02	0.02	0.00	56.48	56.48	0.00
Thames D/S Bulstake	47.102	1.58	1.09	-0.49	54.71	54.71	-0.01
Weirs Mill U/S Longbridges	46h.040H	1.65	1.49	-0.17	54.71	54.71	-0.01
D/S Weirs Mill structures	46h.070A	1.65	1.48	-0.17	53.90	53.90	0.00
U/S Iffley Weirs	TH47_003	0.49	0.43	-0.06	54.71	54.71	-0.01
D/S Iffley Weir	46.052	0.49	0.43	-0.06	53.90	53.90	0.00
U/S Sandford Lock	46c_002A	0.53	0.53	0.00	53.90	53.90	0.00
Downstream Sandford	45.164	2.67	2.67	0.00	50.13	50.13	0.00
Head of Bulstake Stream	BS01.071	0.01	0.01	0.00	56.48	56.48	0.00
Bulstake U/S Botley Road	47k.017	0.42	0.38	-0.04	54.74	54.61	-0.13
Bulstake Stream Willow Walk	BS01.038	0.42	0.38	-0.04	54.73	54.59	-0.14
Botley Stream	BoT07.005	0.40	0.37	-0.03	54.79	54.71	-0.09
Osney Ditch	OD01.011su	0.00	0.00	0.00	55.00	54.99	-0.01
Osney Stream	47q.021	0.24	0.23	-0.01	55.10	55.10	0.00
Eastwyke Ditch at Railway	EW01.022	-0.26	0.00	0.26	54.64	54.41	-0.24
Hinksey Str, Devils Backbone	HS2.001	0.51	0.01	-0.50	54.26	54.27	0.01
Hinksey Stream Railway Bridge	E-00690b	0.00	0.55	0.55	54.23	54.04	-0.20
Hinksey Drain	ditch1uu	0.51	0.00	-0.51	54.13	53.90	-0.23
Mayweed Bridge	46g.012C	0.00	0.55	0.55	53.90	53.90	0.00
Redbridge Stream	L-00683d	0.01	0.01	0.00	54.09	54.09	0.00
Strouds Bridge	Q-00177a	0.32	-0.02	-0.34	53.94	53.90	-0.04
Mundays Bridge	MU01.005	0.20	0.21	0.01	53.90	53.90	0.00

The impact of the FAS on flow splits and water levels are summarised below:

- No impact in flow and water levels on the Thames upstream and including Osney Weir/Lock.
- No impact on flows passing into the Seacourt Stream from the River Thames (u/s Kings Weir).
- At the Seacourt/Botley Stream divergence, due to the downstream FAS works on Seacourt. Stream an additional 0.03m^3/s would flow in Seacourt Stream, water levels are 0.02m lower.
- In the Bulstake Stream, the downstream FAS works intercept the stream and reduce water levels by 0.13m at Botley Road. The flows are also lower due to the reduced flow from Botley Stream.
- Due to the FAS intercepting the Bulstake Stream (flow does not return to the Thames), the Thames flow (d/s Bulstake confluence) reduces by 0.49m^3/s, the water level drops by 0.01m.
- The lower flow in the Thames reduces the flow to Weirs Mill Stream by 0.17m^3/s, Eastwyke Ditch by 0.02m^3/s and Iffley by 0.06m^3/s, water levels are 0.01m.
- A new structure on Eastwyke Ditch (point 2 in Figure 26) will stop flows passing from the Thames to Hinksey Stream, to offset the flows lost to the Thames upstream, 0.26m^3/s, would remain in the Thames
- As Seacourt Stream joins the new western conveyance channel, flows in Hinksey Stream reduce by 0.50m^3/s. However the water level will be similar due to a flow control structure added at the end of the fishing lakes (point 3 in Figure 26) at the Cold Harbour railway bridges. A small flow could be introduced to Hinksey Stream, where the channel diverges from the new conveyance channel to keep a sweetening flow though the ponds (point 1 in Figure 26).

- There is uncertainty to the split of low flows in Hinksey Stream upstream of the Cold Harbour railway bridges (survey request for detailed design stage). Under the FAS a new structure will be added (point 4 in Figure 26) to direct the majority of the flow via Hinksey Stream.

The updated model schematisation for low flows allows for a stable and successful simulation of the Q95 flow scenario. Under the current 'Do Minimum' conditions the model results also show good agreement with the flow splits presented in the Thames Water/Atkins study.

Technical report IMSE500177-HGL-01-ZZ-RE-N-000148-Geomorphological_Modelling_Report should be referred to for details of the impact on sediment transport before and after the implementation of the FAS.

Sensitivity Testing of Outline Design

During the development hydraulic model for the outline design, a number of assumptions to define model parameters, to some degree, remain uncertain. Whilst the calibration and validation of the model provides confidence that the baseline parameters we have adopted are realistic, we have set up a suite of sensitivity tests to explore a wider and credible range of alternative parameter values (for example channel roughness) to understand how robust the performance of the scheme is.

The sensitivity tests detailed in Table 41 (roughness) and Table 42 (coefficients and blockages) are tested using the outline design model for the 100 year event, the tables include a summary of the results.

Table 41: Outline Design model Sensitivity Tests - roughness

Test Ref	Parameter or Variable	Description of sensitivity test and purpose	Summary of results (based on locations presented in results tables
1	1D Roughness (river bed/banks) All model sections	Model run with (a) 20% increase and (b) 20% decrease (global) in channel roughness. Purpose is to explore sensitivity of design to uncertainty in this partly subjective model parameter.	a) 20% increase results in a maximum rise of +0.24m, this is downstream of Sandford Lock, where the results would be influenced by a greater extent as the final model 1D sections are all extended, so floodplain roughness has also increased. Elsewhere, the largest increase is located within the new channel at Abingdon Road and A234 (+0.21m).
			b) 20% decrease results in a maximum reduction of -0.30m within the new channel at the A234.
2	1D Roughness (river bed/banks) Only sections representing the new channel	Model run with (a) 20% increase and (b) 20% decrease (global) in channel roughness. Purpose is to explore sensitivity of design to uncertainty in this partly subjective model parameter.	a) 20% increase results in a maximum rise of +0.09m, within the new channel at the A234.
			b) 20% decrease results in a maximum reduction of -0.11m within the new channel at the A234.
3	2D Roughness (floodplain)	Model run with (a) 20% and (b) 50% increase and (c) 20% decrease (global) in floodplain roughness. Purpose is to explore sensitivity of design to uncertainty in to this partly subjective model parameter and seasonal increases during summer.	a) 20% increase results in a maximum rise of +0.04m.
			b) 50% increase results in a maximum rise of +0.10m
			c) 20% decrease results in a maximum reduction of -0.05m

Tables of peak water levels at the telemetry sites and within the new channels are included in Table 43 (1D roughness), Table 44 (2D Roughness), Table 45 (Structure Coefficients) and Table 46 (Blockages)

Table 42: Outline Design model Sensitivity Tests – coefficients and blockages

Test Ref	Parameter or Variable	Description of sensitivity test and purpose	Summary of results (based on locations presented in results tables
4	Thames weir discharge coefficients	Model run with (a) 20% increase and (b) 20% decrease on weir coefficients. Purpose is to explore sensitivity of the model and the scheme to different (valid) assumptions relating to how much resistance water encounters when flowing through large structures.	a) 20% coefficient increase results in higher flows across the weirs, reducing levels upstream of all Thames weirs. The maximum reduction is -0.14m at Godstow. There is a minor impact on levels in the new channels (-0.01m).
			b) 20% coefficient reduction results in lower flows across the weirs, increasing levels upstream of all Thames weirs. The maximum increase is 0.18m at Godstow. There is a minor impact on levels in the new channels (+0.01m).
5	Bridge and culvert losses	Model run with (a) 20% increase and (b) 20% decrease on bridge and culvert losses on the structures only included on the new channel. Purpose is to explore sensitivity of the model and the scheme to different (valid) assumptions relating to how much resistance water encounters when flowing through bridges and culverts.	a) 20% coefficient increase results in higher losses at bridges and culverts, The impacts are small (+0.01) as the majority of structures within the new channel are bypassed in the floodplains and there are low velocities in the channels.
			b) 20% coefficient decrease results in reduced losses at bridges and culverts, The impacts are small (-0.01) as the majority of structures within the new channel bypassed in the floodplains and there are low velocities in channels.
6	Bridge or Culvert blockages	Model run with 50% blockage at key structures. Purpose is to explore sensitivity of the model and the scheme to potential blockages at (a) Botley Road (Seacourt Stream) (b) Willow Walk (New Bridge) (c) Abingdon Road (New Culvert) (d) Mundays Bridge	a) Botley Road (Seacourt Stream), increases levels upstream by +0.16m, resulting in reduced flows to the new channel, where reductions in peak water level are predicted (bridge is at the start of the new channel). The peak levels in the Thames at Osney increase due to increase flows due to the blockage location.
			b) Willow Walk (New Bridge), increases levels upstream by +0.16m, with increased levels further upstream +0.03 at Botley Road and Osney Lock +0.02m.
			c) Abingdon Road (New Culvert) increases levels upstream by +0.12m, the reduced flow though the culverts, reduces level downstream by -0.05m. Flows increase though Cold Harbour with levels increasing by +0.08m.
			d) Mundays Bridge increase levels locally +0.21m upstream, +0.13m A423 and +0.04m upstream at Cold Harbour.

9.1 Sensitivity to 1D roughness

Table 43: Outline Design Sensitivity – 1D roughness

Location (model node)	Base	1a	Diff (m)	1b	Diff (m)	2a	Diff (m)	2b	Diff (m)
Kings Lock Head (50.008)	59.59	59.58	0.00	59.59	0.00	59.59	0.00	59.59	0.00
Kings Lock Tail (49.050)	59.22	59.28	0.05	59.16	-0.06	59.22	0.00	59.22	0.00
Godstow Lock Head (49.003U)	58.48	58.42	-0.06	58.55	0.07	58.48	0.00	58.48	0.00
Godstow Lock Tail (48.085)	58.05	58.13	0.07	57.95	-0.10	58.06	0.00	58.05	0.00
Osney Lock Head (48.HRU)	56.89	56.96	0.07	56.85	-0.04	56.92	0.03	56.86	-0.03
Osney Lock Tail (47.125)	56.47	56.61	0.14	56.33	-0.13	56.50	0.03	56.43	-0.04
Iffley Lock Head (TH47_003)	55.65	55.72	0.07	55.57	-0.08	55.66	0.02	55.62	-0.02
Iffley Lock Tail (46.052)	55.36	55.52	0.16	55.20	-0.16	55.39	0.03	55.33	-0.03
Sandford Lock Head (46c_002A)	54.60	54.66	0.06	54.60	0.00	54.60	0.00	54.60	0.00
Sandford Lock Tail (45.164)	54.15	54.38	0.23	53.90	-0.24	54.15	0.00	54.15	0.00
(1) Minns Estate (SS-100)	56.96	57.08	0.12	56.80	-0.16	57.01	0.05	56.90	-0.07
New Botley (47k.017)	57.14	57.24	0.10	57.00	-0.14	57.17	0.03	57.10	-0.04
Cold Harbour (46g.012C)	56.06	56.25	0.18	55.83	-0.23	56.14	0.07	55.99	-0.07
Ice Rink (47f.103F)	56.34	56.50	0.16	56.15	-0.19	56.38	0.04	56.29	-0.04
Cherwell (CH.014)	56.56	56.75	0.19	56.40	-0.16	56.60	0.04	56.52	-0.05
(1) Seacourt Stream (47m.036B)	57.34	57.46	0.12	57.18	-0.16	57.38	0.04	57.29	-0.05
(1) Willow Walk (2B_685)	56.66	56.77	0.11	56.51	-0.15	56.69	0.03	56.61	-0.05
(1) Nr Eastwyke Ditch (3A_1135)	56.38	56.53	0.15	56.20	-0.18	56.43	0.05	56.33	-0.05
(1) Devils Backbone (3A_2095)	56.29	56.47	0.18	56.06	-0.23	56.35	0.06	56.23	-0.06
(1) Cold Harbour Bridges (4A_555)	56.21	56.40	0.19	55.94	-0.26	56.28	0.07	56.13	-0.08
(1) Abingdon Road (4E_294)	56.15	56.35	0.21	55.86	-0.28	56.23	0.08	56.06	-0.09
(1) A423 (hin3b5u)	55.61	55.82	0.21	55.31	-0.30	55.70	0.09	55.50	-0.11
(1) MU01.005 (Mundays Bridge)	55.40	55.55	0.15	55.15	-0.25	55.42	0.02	55.38	-0.02

(1) New channel or modified channel

9.2 Sensitivity to 2D roughness

Table 44: Outline Design Sensitivity – 2D roughness

Location (model node)	Base	3a	Diff (m)	3b	Diff (m)	3c	Diff (m)
Kings Lock Head (50.008)	59.59	59.60	0.02	59.64	0.05	59.57	-0.02
Kings Lock Tail (49.050)	59.22	59.26	0.04	59.32	0.10	59.19	-0.03
Godstow Lock Head (49.003U)	58.48	58.52	0.04	58.58	0.10	58.43	-0.05
Godstow Lock Tail (48.085)	58.05	58.08	0.03	58.12	0.06	58.03	-0.03
Osney Lock Head (48.HRU)	56.89	56.90	0.01	56.92	0.03	56.88	-0.01
Osney Lock Tail (47.125)	56.47	56.48	0.01	56.49	0.03	56.45	-0.01
Iffley Lock Head (TH47_003)	55.65	55.66	0.02	55.68	0.04	55.63	-0.02
Iffley Lock Tail (46.052)	55.36	55.39	0.03	55.43	0.07	55.32	-0.03
Sandford Lock Head (46c_002A)	54.60	54.63	0.03	54.67	0.08	54.56	-0.04
Sandford Lock Tail (45.164)	54.15	54.16	0.01	54.17	0.02	54.14	-0.01
(1) Minns Estate (SS-100)	56.96	56.97	0.01	56.99	0.03	56.94	-0.02
New Botley (47k.017)	57.14	57.15	0.01	57.17	0.03	57.12	-0.02
Cold Harbour (46g.012C)	56.06	56.07	0.01	56.08	0.02	56.06	-0.01
Ice Rink (47f.103F)	56.34	56.35	0.02	56.37	0.04	56.32	-0.02
Cherwell (CH.014)	56.56	56.57	0.01	56.59	0.02	56.55	-0.01
(1) Seacourt Stream (47m.036B)	57.34	57.35	0.01	57.36	0.01	57.33	-0.01
(1) Willow Walk (2B_685)	56.66	56.68	0.02	56.71	0.05	56.62	-0.04
(1) Nr Eastwyke Ditch (3A_1135)	56.38	56.40	0.02	56.42	0.04	56.36	-0.02
(1) Devils Backbone (3A_2095)	56.29	56.30	0.01	56.32	0.03	56.28	-0.01
(1) Cold Harbour Bridges (4A_555)	56.21	56.21	0.01	56.22	0.01	56.20	0.00
(1) Abingdon Road (4E_294)	56.15	56.15	0.00	56.15	0.00	56.15	0.00
(1) A423 (hin3b5u)	55.61	55.63	0.02	55.66	0.05	55.59	-0.02
(1) MU01.005 (Mundays Bridge)	55.40	55.43	0.03	55.48	0.08	55.36	-0.04

(1) New channel or modified channel

9.3 Sensitivity to structure coefficients

Table 45: Outline Design Sensitivity – structure coefficients

Location (model node)	Base	4a	Diff (m)	4b	Diff (m)	5a	Diff (m)	5b	Diff (m)
Kings Lock Head (50.008)	59.59	59.56	-0.02	59.61	0.02	59.59	0.00	59.59	0.00
Kings Lock Tail (49.050)	59.22	59.24	0.02	59.21	-0.01	59.22	0.00	59.22	0.00
Godstow Lock Head (49.003U)	58.48	58.34	-0.14	58.66	0.18	58.48	0.00	58.48	0.00
Godstow Lock Tail (48.085)	58.05	58.08	0.02	58.02	-0.04	58.06	0.00	58.05	0.00
Osney Lock Head (48.HRU)	56.89	56.86	-0.03	56.97	0.08	56.90	0.01	56.88	-0.01
Osney Lock Tail (47.125)	56.47	56.47	0.00	56.46	0.00	56.47	0.00	56.46	-0.01
Iffley Lock Head (TH47_003)	55.65	55.62	-0.03	55.69	0.04	55.65	0.00	55.64	0.00
Iffley Lock Tail (46.052)	55.36	55.35	-0.01	55.37	0.01	55.36	0.00	55.36	0.00
Sandford Lock Head (46c_002A)	54.60	54.53	-0.07	54.67	0.07	54.60	0.00	54.60	0.00
Sandford Lock Tail (45.164)	54.15	54.15	0.00	54.15	0.00	54.15	0.00	54.15	0.00
(1) Minns Estate (SS-100)	56.96	56.96	0.00	56.97	0.01	56.96	0.00	56.96	0.00
New Botley (47k.017)	57.14	57.14	0.00	57.15	0.01	57.15	0.01	57.13	-0.01
Cold Harbour (46g.012C)	56.06	56.06	0.00	56.07	0.01	56.07	0.00	56.06	-0.01
Ice Rink (47f.103F)	56.34	56.34	0.00	56.34	0.01	56.34	0.01	56.33	-0.01
Cherwell (CH.014)	56.56	56.56	0.00	56.58	0.01	56.57	0.01	56.55	-0.01
(1) Seacourt Stream (47m.036B)	57.34	57.34	0.00	57.35	0.01	57.36	0.01	57.33	-0.02
(1) Willow Walk (2B_685)	56.66	56.66	0.00	56.66	0.00	56.67	0.01	56.65	-0.01
(1) Nr Eastwyke Ditch (3A_1135)	56.38	56.38	0.00	56.39	0.00	56.39	0.00	56.38	0.00
(1) Devils Backbone (3A_2095)	56.29	56.29	0.00	56.30	0.01	56.30	0.01	56.28	-0.01
(1) Cold Harbour Bridges (4A_555)	56.21	56.20	0.00	56.21	0.01	56.21	0.00	56.20	0.00
(1) Abingdon Road (4E_294)	56.15	56.14	0.00	56.15	0.01	56.15	0.01	56.14	-0.01
(1) A423 (hin3b5u)	55.61	55.61	-0.01	55.62	0.01	55.61	0.00	55.62	0.00
(1) MU01.005 (Mundays Bridge)	55.40	55.39	-0.01	55.41	0.01	55.40	0.00	55.40	0.00

(1) New channel or modified channel

9.4 Sensitivity to blockages

Table 46: Outline Design Sensitivity – blockages

Location (model node)	Base	6a	Diff (m)	6b	Diff (m)	6c	Diff (m)	6d	Diff (m)
Kings Lock Head (50.008)	59.59	59.59	0.00	59.59	0.00	59.59	0.00	59.59	0.00
Kings Lock Tail (49.050)	59.22	59.23	0.00	59.22	0.00	59.22	0.00	59.22	0.00
Godstow Lock Head (49.003U)	58.48	58.48	0.00	58.48	0.00	58.48	0.00	58.48	0.00
Godstow Lock Tail (48.085)	58.05	58.07	0.02	58.06	0.00	58.06	0.00	58.05	0.00
Osney Lock Head (48.HRU)	56.89	56.99	0.10	56.91	0.02	56.90	0.01	56.90	0.01
Osney Lock Tail (47.125)	56.47	56.50	0.03	56.47	0.01	56.49	0.03	56.48	0.01
Iffley Lock Head (TH47_003)	55.65	55.65	0.00	55.65	0.00	55.66	0.01	55.65	0.00
Iffley Lock Tail (46.052)	55.36	55.36	0.00	55.36	0.00	55.36	0.01	55.36	0.00
Sandford Lock Head (46c_002A)	54.60	54.60	0.00	54.60	0.00	54.60	0.00	54.60	0.00
Sandford Lock Tail (45.164)	54.15	54.15	0.00	54.15	0.00	54.15	0.00	54.15	0.00
(1) Minns Estate (SS-100)	56.96	56.76	-0.20	57.03	0.06	56.97	0.01	56.97	0.00
New Botley (47k.017)	57.14	57.26	0.12	57.17	0.03	57.15	0.01	57.14	0.00
Cold Harbour (46g.012C)	56.06	56.06	-0.01	56.06	0.00	56.15	0.08	56.11	0.04
Ice Rink (47f.103F)	56.34	56.35	0.01	56.34	0.00	56.38	0.04	56.36	0.02
Cherwell (CH.014)	56.56	56.66	0.10	56.58	0.02	56.59	0.03	56.57	0.01
(1) Seacourt Stream (47m.036B)	57.34	57.51	0.16	57.37	0.03	57.35	0.00	57.35	0.00
(1) Willow Walk (2B_685)	56.66	56.59	-0.07	56.82	0.16	56.68	0.02	56.67	0.01
(1) Nr Eastwyke Ditch (3A_1135)	56.38	56.37	-0.01	56.38	0.00	56.43	0.05	56.40	0.02
(1) Devils Backbone (3A_2095)	56.29	56.28	-0.01	56.29	0.00	56.36	0.07	56.32	0.03
(1) Cold Harbour Bridges (4A_555)	56.21	56.20	-0.01	56.21	0.00	56.29	0.09	56.25	0.04
(1) Abingdon Road (4E_294)	56.15	56.14	-0.01	56.15	0.00	56.26	0.12	56.20	0.05
(1) A423 (hin3b5u)	55.61	55.61	0.00	55.61	0.00	55.56	-0.05	55.74	0.13
(1) MU01.005 (Mundays Bridge)	55.40	55.40	0.00	55.40	0.00	55.38	-0.02	55.60	0.21

(1) New channel or modified channel

SECTION 10

Conclusions

10.1 Model update and calibration

During the model update, care was taken to ensure the model remained stable and ran successfully. Particularly as the updates replaced 2D only channels with linked 1D-2D reaches to provide a more robust and consistent approach to modelling significant watercourses.

Roughness values and coefficients of approach velocity on structures were compared between previous modelling studies undertaken by Mott MacDonald (2014) and Black & Veatch (2009). The values adopted in the updated model generally sit between these values.

The model update and subsequent calibration and validation work undertaken by CH2M has greatly improved the performance of the model when compared with observed events, particularly for the 2007 flood. The model's improved performance is a result of improved model schematisation (for example, by incorporating more recent survey) and improved model parameters (for example, channel roughness).

Given the successful outcome of the re-calibration and validation exercise, the calibrated model is now considered to be suitable for supporting the development of options and their outline design which is included in this report.

10.2 Outline Design

Flood Flows

The modelling of the outline design has shown to reduce the flood risk in Oxford. The combination of the new channel and raised defences upstream of Botley Road and in New Hinksey protect a large number of properties.

For the 100 year event, peak water levels are predicted to be reduced by approximately 0.20m upstream of Botley Road and 0.21m at Abingdon Road (Mayweed Bridge). The new channel increases the flow capacity west of the railway, reducing the peak flow in the Thames, downstream of the Bulstake Stream confluence the flows are predicted to be reduced by 16m^3/s. Further downstream, at the A423 crossing the Thames/Weir Mill Stream flows are further reduced by 39m^3/s due to new culverts under Abingdon Road and the flow control on Eastwyke ditch which reduce the cross flows over the railway and from Redbridge stream (Cold Harbour)

The model predicts the flows downstream of Sandford to be slightly reduced at peak flows (1m^3/s for 100 year event) with a slight increase in flow on the rising limb, due to the improved conveyance of the new channel.

Low Flows

Comparison with the FAS outline design model, shows changes in flow splits and water levels which can be further investigated as the scheme progresses through detailed design. Reassuringly, the FAS is shown to have no impact on river levels and flows adjacent to Port Meadow. However, water levels do change in the vicinity of Iffley Meadow, and this is something that will need closer analysis as the scheme design is progressed. The potential impact of lower Thames flows on navigation between Osney and Sandford Locks should also be considered with the Environment Agency's navigation team.

10.3 Accompanying technical Reports

The following technical reports should be referenced for details on model development, hydrology, calibration, economics, geomorphology and groundwater modelling:

Model review and updates

IMSE500177-HGL-00-ZZ-RE-N-000074

Hydrology

IMSE500177-HGL-00-ZZ-RE-N-000077

Calibration

IMSE500177-HGL-00-ZZ-RE-N-000075

Economic Assessment

Report number not yet issued (at draft stage)

Geomorphological Impacts

IMSE500177-HGL-01-ZZ-RE-N-000148

Groundwater Modelling

Report number not yet issued (at draft stage)

SECTION 11

Recommendations for detailed design modelling

Based on the modelling undertaken to represent current conditions and the outline design, the following items are recommended for the detailed design modelling stage:

- Glass walling of the 1D model is present in the model results (1000 year only) for the proposed new channel at the A423. During detailed design, the location and length of the new channel and culvert configuration will be confirmed and bank levels set on the new 1D channel cross sections. If required, depending on peak water levels, these 1D sections could be linked to 2D.
- Survey is planned for the Weirs Mill Stream, to improve the confidence in the channel capacity and determine if works to improve conveyance are required. The current available cross sectional data is limited and does appear to represent varying shape of the channel.
- To improve confidence in low flows at Cold Harbour, survey is required on the Towles Mill structures and the sluice which is assumed to exist at the end of the pond, west of the railway. The data will be used to confirm locally, the Q95 water levels, to allow crest levels to be set on the proposed low flow structures.
- Action 'amber' flagged comments in Peer review 5, which includes cross section with of 4A_555, 2D roughness along railway, oscillations between 1D/2D (nodes Ditch1dd to R-00250r and S-00289ad) and model tidy up of redundant bank z-lines (LiDAR along HQ lines preferred to z-line)

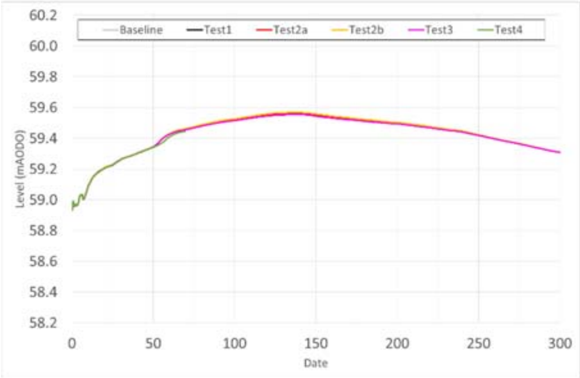
Appendix A
Peer Review 2 Sensitivity Tests

Table A1: Results of Peer Review 2 sensitivity tests

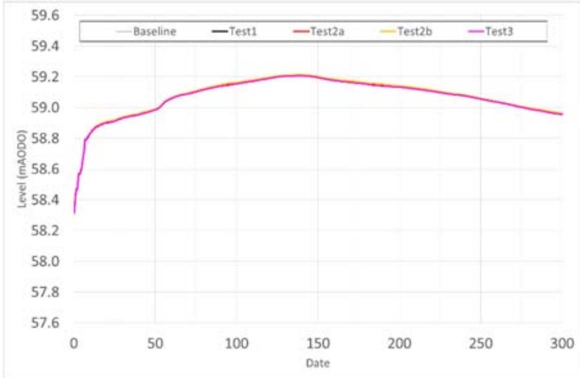
Location (model node)	Baseline (mAOD)	Test1 (mAOD)	Difference (m)	Test2a (mAOD)	Difference (m)	Test2b (mAOD)	Difference (m)	Test3 (mAOD)	Difference (m)
Kings Lock Head (50.008)	59.56	59.56	0.00	59.56	0.01	59.57	0.01	59.56	0.00
Kings Lock Tail (49.050)	59.21	59.21	0.00	59.21	0.00	59.21	0.01	59.21	0.00
Godstow Lock Head (49.003U)	58.45	58.45	0.00	58.45	0.00	58.45	0.00	58.45	0.00
Godstow Lock Tail (48.085)	58.03	58.03	0.00	58.03	0.01	58.04	0.01	58.03	0.00
Osney Lock Head (48.HRU)	57.01	57.01	0.01	57.01	0.01	57.02	0.01	57.01	0.00
Osney Lock Tail (47.125)	56.57	56.57	0.00	56.57	0.01	56.58	0.01	56.57	0.00
Iffley Lock Head (TH47_003)	55.66	55.67	0.00	55.67	0.01	55.68	0.02	55.66	0.00
Iffley Lock Tail (46.052)	55.39	55.39	0.00	55.40	0.01	55.40	0.01	55.39	0.00
Sandford Lock Head (46c_002A)	54.52	54.52	0.00	54.52	0.01	54.53	0.01	54.53	0.01
Sandford Lock Tail (45.164)	54.07	54.08	0.00	54.08	0.01	54.09	0.02	54.19	0.12
Minns Estate (47m.26B)	57.18	57.18	0.00	57.19	0.01	57.19	0.01	57.18	0.00
New Botley (47k.017)	57.27	57.28	0.01	57.28	0.01	57.29	0.02	57.27	0.00
Cold Harbour (46g.012C)	56.26	56.26	0.00	56.27	0.01	56.27	0.01	56.26	0.00
Ice Rink (47f.103F)	56.44	56.44	0.00	56.45	0.01	56.45	0.01	56.44	0.00
Cherwell (CH.014)	56.19	56.19	0.01	56.20	0.01	56.21	0.02	56.19	0.00

Location (model node)	Baseline (m^3/s)	Test1 (m^3/s)	Difference (m^3/s)	Test2a (m^3/s)	Difference (m^3/s)	Test2b (m^3/s)	Difference (m^3/s)	Test3 (m^3/s)	Difference (m^3/s)
Outflow (d/s Sandford 45.128)	272.63	272.80	0.17	273.62	0.98	275.03	2.40	272.45	-0.18

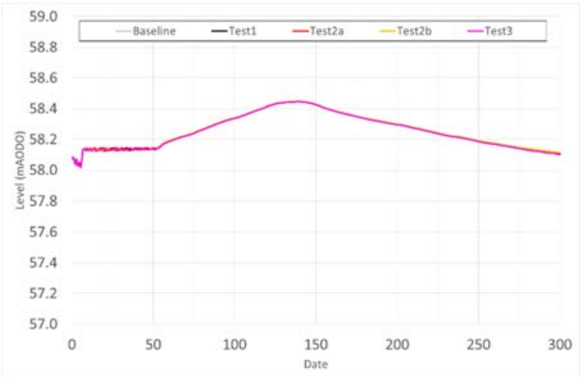
Kings Lock Head



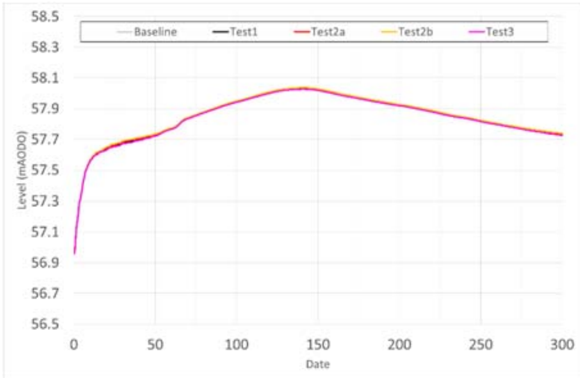
Kings Lock Tail



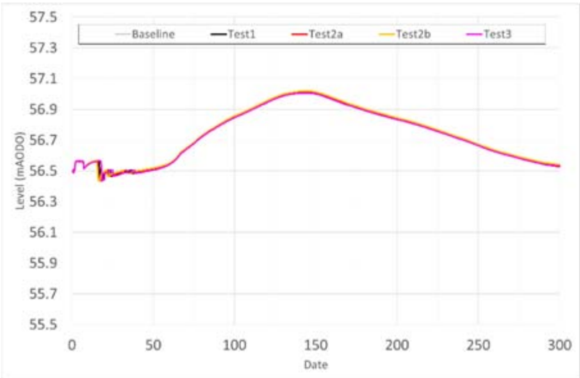
Godstow Lock Head



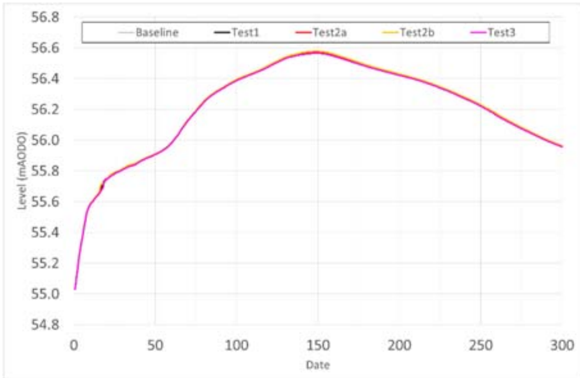
Godstow Lock Tail



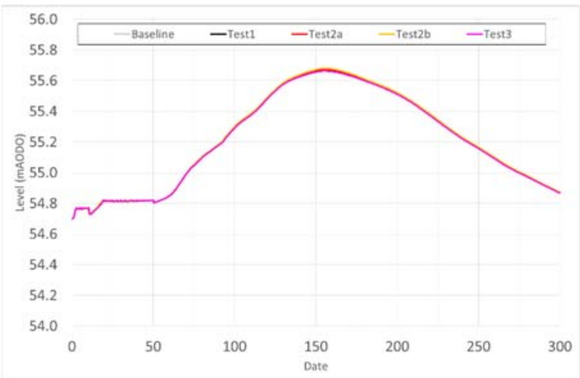
Osney Lock Head



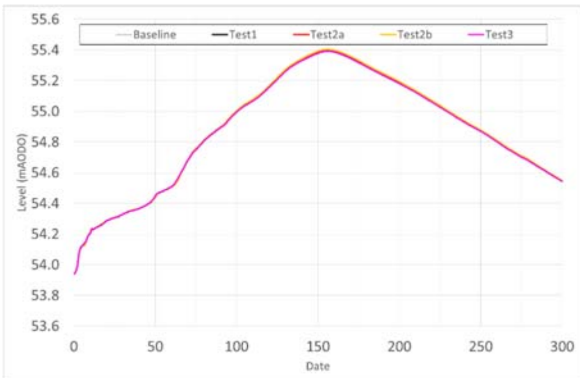
Osney Lock Tail



Iffley Lock Head



Iffley Lock Tail



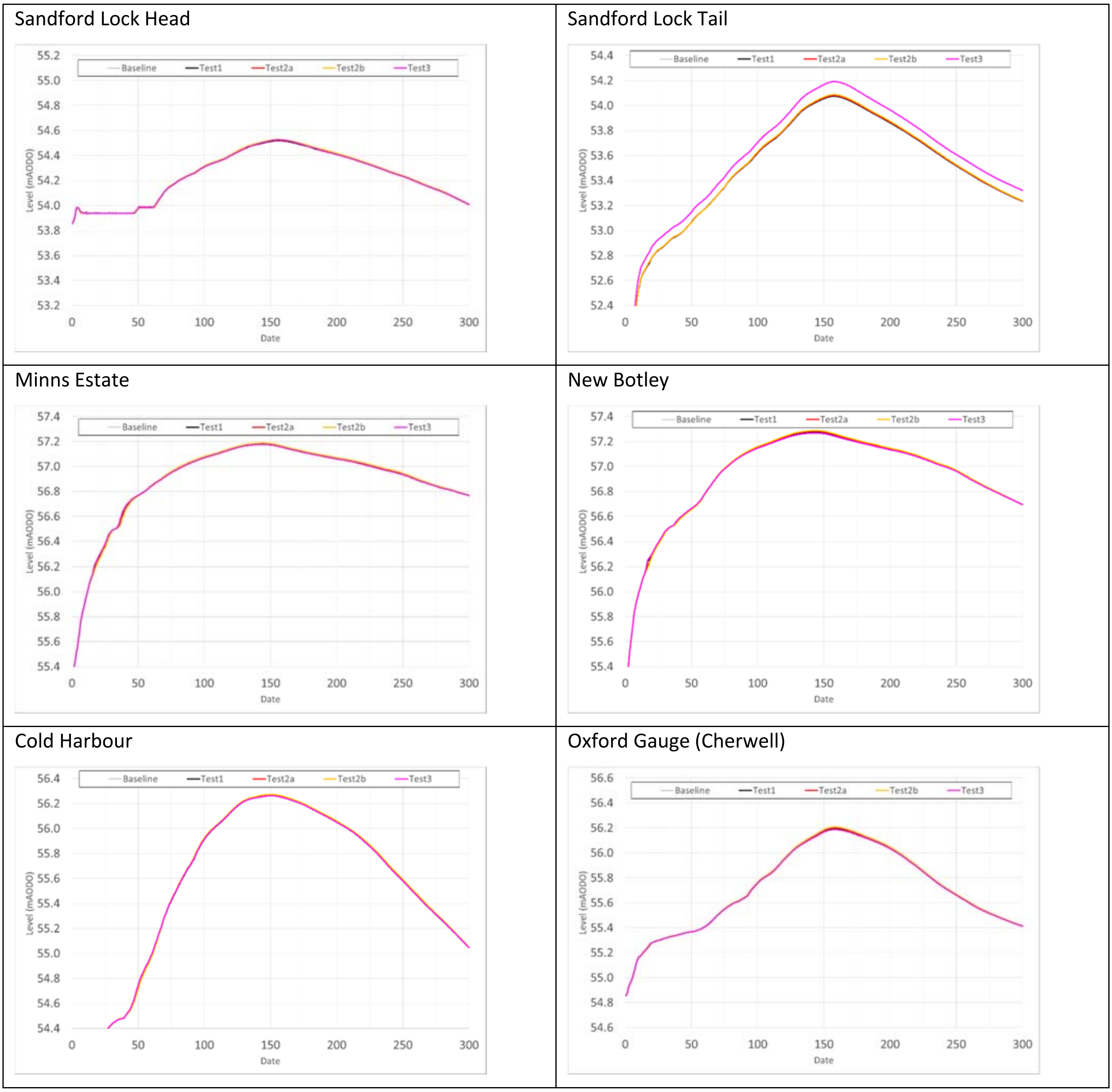


Figure A1: Peer 2 review, comparion of water levels at telemetry stations

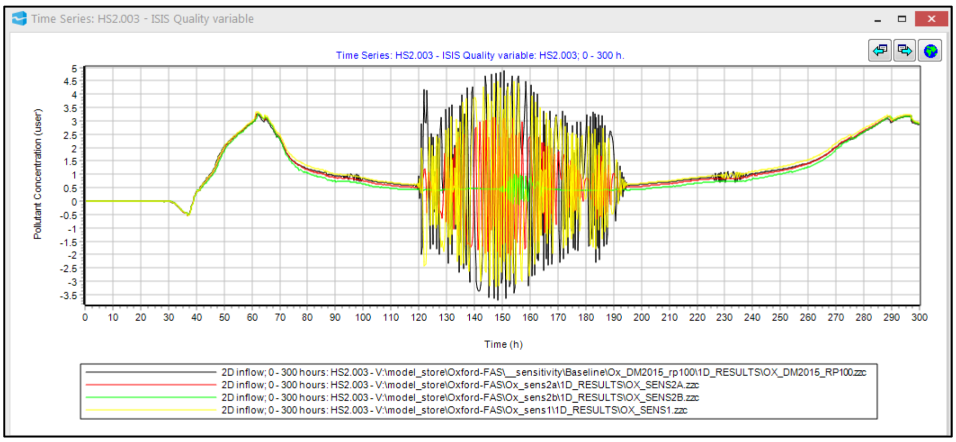


Figure A2: Peer 2 review, exampled 1D/2D flow improvement following HX line energy loss

Appendix B
Do Minimum and Do Nothing Model Assumptions

Table B1: Do Minimum model assumptions

	List of Structures	Assumptions	Application in the Hydraulic Modelling: Year 0 – Year 59	Application in the Hydraulic Modelling: Year 60 - 99	Application in the Economic Modelling
Lock structures (req' for navigation)	- Osney Lock - Iffley Lock - Sandford Lock	- We have assumed that the locks remain closed at all times.	- Locks are assumed to always be closed and are not included in the model.		
Navigation sluices	Sluices associated with: - Osney Lock - Iffley Lock - Sandford Lock	- We **will** operate, maintain and repair navigation sluices. - We **will** operate the sluices in a flood event.	- Based on the Thames Weir Strategy, we assume that the sluices will be maintained for the rest of their residual life, 60 years. After this time we have assumed that the gates are washed away. We have assumed that existing assets are generally in a good condition and therefore there is a linear increase in the probability of failure from Year 0 to Year 60.	- Open	- Refer to methodology for calculating Do Minimum Damages (Appendix A Economics Report)
Flow control structures (not req' for navigation purposes)	- Bulstake; Bathing weirs - Weirs Mill Sluices	- We **will** operate, maintain and repair flow control structures. - We **will** operate the flow control structures in a flood event.	- Based on the Thames Weir Strategy, we assume that the flow control structures will be maintained for the rest of their residual life, a maximum of 60 years. We have assumed that existing assets are generally in a good condition and therefore there is a linear increase in the probability of failure from Year 0 to Year 60.	- Open	- Refer to methodology for calculating Do Minimum Damages (Appendix A Economics Report)
Channels **with and without** engineered banks	- Thames - Cherwell - Botley Stream - Bulstake - Seacourt Stream - Hinksey Stream - Hinksey Drain	We **will** continue to carry out the following throughout the 100 year appraisal period: - debris clearance or weeding; and, - undertake dredging for navigation or other reasons. - We will maintain, patch and repair engineered banks until they eventually fail and erode to a 'natural bank'.	- We assume that no vegetation accumulation occurs along the river banks throughout the appraisal period as maintenance is continued; therefore no adjustment to Manning's 'n'. - We assume that no siltation occurs in the channel throughout the appraisal period as channel maintenance is continued; therefore no adjustment to Manning's 'n'.		- Refer to methodology for calculating Do Minimum Damages (Appendix A Economics Report)
Bridges and culverts	- Botley Road Bridge over the River Thames - All other culverts and bridges over the River Thames - All bridges over all other watercourses.	We **will** continue to carry out the following throughout the 100 year appraisal period: - debris clearance or weeding; and, - undertake dredging for navigation or other reasons. - Road / rail authorities will maintain the structural integrity of such structures.	- We assume that no debris or vegetation builds up at the entrance to bridges / culverts throughout the appraisal period as maintenance is continued; therefore no adjustment to Manning's 'n'.		- Refer to methodology for calculating Do Minimum Damages (Appendix A Economics Report)
Existing raised flood defences	There are **Temporary** flood defences in the Oxford area, we assume temporary defences will be deployed from year 0 to year 34. From Year 35, they temporary flood defences will be removed.				
Construct new flood mitigation works	We will **not** carry out any new works to mitigate flood risk.				

Table B2: Do Nothing model assumptions

	List of Structures	Assumptions	Application in the Hydraulic Modelling: Year 0 – Year 19	Application in the Hydraulic Modelling: Year 20 – Year 49	Application in the Hydraulic Modelling: Year 50 – Year 99	Application in the Economic Modelling
Lock structures (req' for navigation)	- Osney Lock - Iffley Lock - Sandford Lock	- We have assumed the locks remain closed at all times.	- Locks are assumed to always be closed and are not included in the model.			- There will be no costs or economic losses associated with these structures.
Navigation sluices	Sluices associated with: - Osney Lock - Iffley Lock - Sandford Lock	- We will **not** operate, maintain, repair or replace navigation sluices. - We **will** leave the sluices **closed**.	- All navigation sluices, associated with the locks, will be modelled as closed based on known structure dimensions. Over time, sluice gates will start to leak and will ultimately fail as their condition deteriorates. Once failed, these structures will be modelled as open. - We assume that no additional blockages occur above the sluice gates.		Open	- There will be no costs associated with these structures. - Linear changes in damages between modelled water levels as the probability of failure of sluices increases.
Flow control structures (not req' for navigation purposes)	- Bulstake; Bathing weirs - Weirs Mill Sluices - Castle Mill Weir	- We will **not** operate, maintain, repair or replace any flow control structures. - We **will** leave the flow control structures **closed**.	- All flow control structures will be modelled as closed based on known structure dimensions. Assumptions as for Navigation Structures above. - We assume that no additional blockages occur above the flow control gates.		Open	- There will be no costs associated with these structures. - Linear changes in damages between modelled water levels as the probability of failure of sluices increases.
Channels **with** and **without** engineered banks	- Thames	We will **not** carry out: - debris clearance or weeding; - maintain, repair or replace any engineered banks. - undertake dredging for navigation or other reasons; or - any other works that intervene in natural processes.	- We assume that as yet no vegetation accumulation has occurred along the river banks; therefore no adjustment to Manning's 'n'. - We assume that no siltation has occurred; therefore no adjustment to Manning's 'n'. - Existing Manning's 'n' values between 0.035 and 0.060 depending on location.	- Manning's 'n' increased by 50% to reflect increase in vegetation accumulation along the river banks. - Manning's 'n' increased by a further 20% to reflect the siltation reducing the cross sectional area by approximately 10%	- Manning's 'n' increased by 50% to reflect increase in vegetation accumulation along the river banks. - Manning's 'n' increased by a further 67% to reflect the siltation reducing the cross sectional area by approximately 25%	- There will be no costs associated with these structures.
	- Cherwell - Botley Stream - Bulstake - Seacourt Stream - Hinksey Stream - Hinksey Drain			- Manning's 'n' increased by 100% to reflect increase in vegetation accumulation along the river banks. - Manning's 'n' increased by a further 33% to reflect the siltation reducing the cross sectional area by approximately 20%	- Manning's 'n' increased by 100% to reflect increase in vegetation accumulation along the river banks. - Manning's 'n' increased by a further 100% to reflect the siltation reducing the cross sectional area by approximately 45%.	- There will be no costs associated with these structures.
Bridges and culverts	- Botley Road bridge over the River Thames	- We will not maintain, repair or replace any culverts (including any associated trash screens). - Road / rail authorities will not maintain the structural integrity of such structures.	- We assume that as yet no debris has accumulated around bridges; therefore no adjustment to Bernoulli's head loss coefficient 'k'. Blockages to small culverts have not been included due to the low conveyance of these structures.	- Bernoulli's head loss coefficient 'k' increased by 300% (c. 50% blockage) to reflect increase in debris accumulating around the bridge.		- There will be no costs associated with these structures.
	- All other culverts and bridges over the River Thames			- Bernoulli's head loss coefficient 'k' increased by 100% (c. 30% blockage) to reflect increase in debris accumulating around the bridge.		
	- All bridges & culverts over all other watercourses.			- Bernoulli's head loss coefficient 'k' increased by 300% (c. 50% blockage) to reflect increase in debris accumulating around the bridge. - Blockage unit added to culvert and bridge type units (50% blockage)		
Existing raised flood defences	There are **no** formal raised flood defences in the Oxford area.					
Construct new flood mitigation works	We will **not** carry out any new works to mitigate flood risk.					

Appendix C
Do Minimum and Do Nothing Model Files

Data Structure

As linked 1D-2D Flood Modeller-TUFLOW models, the Do Minimum and Do Nothing models all follow a consistent data structure format. Table C1, below, summarises the model file structure, and the files' relationships to each other.

Table C1: Model file structure

Component	Run file	Referenced files	Comments
1D (Flood Modeller)	.IEF	• .DAT • .IED • results	• 1D model • 1D boundary files • 1D results
2D (TUFLOW)	.TCF	• .TGC • .TMF • .TBC • .TLF • checks • results	• 2D geometry control file • 2D materials file • 2D boundary file • 2D log file • 2D check files • 2D results files

Model File Names

The key model run files for Do Minimum and Do Nothing are presented in Table C2 and Table C3.

Table C2: Model run files for Do Minimum

File	Year 0 (2015)	Year 35 (2050)
1D run file	Ox_DM2015_<RP>_v1.ief	Ox_DM2050_<RP>y35_v1.ief
1D model file	Ox_DM2015.DAT	Ox_DM2015.DAT
1D boundary files	y0_<RP>.IED	Y35_<RP>.IED
2D run file	Ox_DM2015_<RP>_v1.tcf	Ox_DM2050_<RP>y35_v1.tcf
2D geometry file	Oxford_DN2015.tgc	Oxford_DM2050.tgc
2D boundary file	Oxford_DM2015a.tbc	Oxford_DM2015a.tbc
2D materials file	Oxford_2D_materials.tmf	Oxford_2D_materials.tmf

Table C3: Model run files for Do Nothing

File	Year 0 (2015)	Year 20 (2035)	Year 50 (2065)
1D run file	Ox_DN2015_<RP>_v1.ief	Ox_DN2035_<RP>y20_v1.ief	Ox_DN2065_<RP>y50_v1.ief
1D model file	Ox_DN2015.DAT	Ox_DN2035.DAT	OX_DN2065.dat
1D boundary files	y0_<RP>.IED	y20_<RP>.IED	y50_<RP>.IED
2D run file	Ox_DN2015_<RP>_v1.tcf	Ox_DN2035_<RP>y20_v1.tcf	Ox_DN2065_<RP>y50_v1.tcf
2D geometry file	Oxford_DN2015.tgc	Oxford_DN2035.tgc	Oxford_DN2035.tgc
2D boundary file	Oxford_DM2015a.tbc	Oxford_DM2015a.tbc	Oxford_DM2015a.tbc
2D materials file	Oxford_2D_materials.tmf	Oxford_2D_materials.tmf	Oxford_2D_materials.tmf

Table C4, lists the GIS layers that form the schematisation of the 2D component of the model.

Table C4: Description of layers used in the 2D (TUFLOW) model component

Layer	Format	Description
1d_nwk_estry_CH2M_devils	Shapefile	ESTRY culvert network for Devils Backbone
1d_nwk_estry_CH2M_willow	Shapefile	ESTRY culvert network for Willow Walk
1d_FM_node_Oxford	Shapefile	ISIS node locations
2d_iwl_Oxford_polygon	Shapefile	Initial water level in certain areas
2d_iwl_lake_Oxford_polygon	Shapefile	Initial water level set in lakes and Hinksey Stream
2d_po_Oxford	Shapefile	Read PO lines
2d_bc_hx_Oxford_HXFLC	Shapefile	Sets HX links between 1D channel & 2D domain
2d_bc_sx_estry_CH2M_devils	Shapefile	Sets SX links for Devils Backbone
2d_bc_sx_estry_CH2M_willow	Shapefile	Sets SX links for Willow Walk
2d_bc_sx_Oxford_20121025_GM01	MapInfo	Sets general SX links
2d_zsh_lakebed_Oxford_polygon	Shapefile	Assumed bed levels in lakes
2d_zsh_banks_Oxford_CH2M_O_polyline	Shapefile	Sets elevations along river banks at 1D-2D link
2d_zsh_banks_Oxford_CH2M_O_point	Shapefile	Sets elevations along river banks at 1D-2D link
2d_zsh_defences_Oxford_polyline	Shapefile	Sets elevations along river banks at 1D-2D link with surveys 11227, 11228, 11230 (dated 2011)
2d_zsh_defences_Oxford_point	Shapefile	Sets elevations along river banks at 1D-2D link with surveys 11227, 11228, 11230 (dated 2011)
2d_zsh_Hinksey_Ditch_polyline	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_Hinksey_Ditch_point	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_Hinksey_Ditch_polygon	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_embankments_Oxford_CH2M_H_polyline	Shapefile	Sets elevations along embankments
2d_zsh_embankments_Oxford_CH2M_H_point	Shapefile	Sets elevations along embankments
2d_zsh_temp_defences	Shapefile	Temporary defences
2d_zsh_flowpaths_Oxford_CH2M_G_polyline	Shapefile	Sets elevations along flow paths
2d_zsh_flowpaths_Oxford_CH2M_G_point	Shapefile	Sets elevations along flow paths
2d_mat_stability_v1	Shapefile	Improve stability at Devil's Backbone and Hinksey
2d_mat_stability_DN	Shapefile	Improve stability for Do Nothing Year 20 and 50
2d_code_Oxford_river.shp	Shapefile	Sets null cells within river channel
2d_loc_Oxford_20120726_GM01	MapInfo	Defines the SW corner/orientation of the 2D grid
2d_code_Oxford_20120928_GM01	MapInfo	Defines the active 2D cells
2d_zsh_DTMfill_Oxford_20120806_GM01	MapInfo	Areas with no LiDAR data get filled in
2d_zsh_rivers_Oxford_CH2M	MapInfo	Sets elevations along river channels
2d_lfcsh_culverts_Oxford_F_polyline	Shapefile	Sets flow constrictions for bridges/culverts along watercourses represented in 2D
2d_mat_manmade_Oxford_20120824_GM0	MapInfo	Define man-made areas
2d_mat_multi_Oxford_20120824_GM01	MapInfo	Define multi-use areas
2d_mat_rail_Oxford_20120824_GM01	MapInfo	Define rail areas

Layer	Format	Description
2d_mat_road_Oxford_20120824_GM01	MapInfo	Define roads
2d_mat_path_Oxford_20120824_GM01	MapInfo	Define paths
2d_mat_rough_ground_Oxford_20120824_GM01	MapInfo	Define rough ground areas
2d_mat_scrub_Oxford_20120824_GM01	MapInfo	Define scrub areas
2d_mat_trees_Oxford_20120824_GM01	MapInfo	Define forested areas
2d_mat_water_Oxford_20120824_GM01	MapInfo	Define water bodies
2d_mat_buildings_Oxford_20120824_GM01	MapInfo	Define building areas
Oxford_DTM_merged	ASCII	Reads in the DTM grid

Run Parameters

The model simulations were run in an unsteady state with a 1.5 second 1D time step and a 3 second 2D time step. The 2D horizontal model resolution is 10 metres.

The model parameters in the .ief run file are primarily set to the default values recommended by Flood Modeller. The exceptions are as follows:

- The **dflood** parameter is set to 10, which allows the 1D cross-sections to glass-wall up to a height of 10m if required, which is considered acceptable for a linked 1D-2D model.
- The **maxitr** parameter is set to 19, which allows the number of iterations per time step for the model to solve the shallow water equations. Performing more iterations increases the probability of model convergence.
- The **Matrix Dummy coefficient** is set to 0.00001, which reduces the probability of the results matrix becoming singular and crashing the model.

Model Outputs

Model results for both the 1D Flood Modeller and 2D TUFLOW components are saved at 15-minute intervals, which limits the results file sizes. Outputs from the 2D component include level, flow, velocity, depth, mass balance and UK Hazard results. Time-series level and flow data within the 2D domain are also output at the PO-line locations within the model.

Appendix D
Peer Review 3 Sensitivity Tests

Table D1: Results of Peer Review 3 sensitivity test at A34 (1000 year event)

Location (model node)	Baseline (mAOD)	Test1 (mAOD)	Difference (m)	Test2 (mAOD)	Difference (m)	Test3 (mAOD)	Difference (m)
Wytham Bridge (47m.065B)	59.16	59.13	-0.02	59.14	-0.01	59.13	-0.02
Section u/s A34 (47m.054B)	59.07	59.04	-0.03	59.05	-0.02	59.04	-0.03
A34 u/s (47m.052B)	58.11	58.11	0.00	58.11	0.00	58.11	0.00
A34 d/s (47m.051B0	58.08	58.08	0.00	58.08	0.00	58.08	0.00
Kings Lock Head (50.008)	59.70	59.70	0.00	59.70	0.00	59.70	0.00
Kings Lock Tail (49.050)	59.46	59.45	-0.01	59.45	0.00	59.45	-0.01
Godstow Lock Head (49.003U)	58.88	58.87	-0.01	58.87	0.00	58.87	-0.01
Godstow Lock Tail (48.085)	58.22	58.22	0.00	58.22	0.00	58.22	0.00
Osney Lock Head (48.HRU)	57.34	57.34	0.00	57.34	0.00	57.34	0.00
Osney Lock Tail (47.125)	56.86	56.86	0.00	56.86	0.00	56.86	0.00
Iffley Lock Head (TH47_003)	56.01	56.01	0.00	56.01	0.00	56.01	0.00
Iffley Lock Tail (46.052)	55.89	55.89	0.00	55.89	0.00	55.89	0.00
Sandford Head (46c_002A)	54.87	54.87	0.00	54.87	0.00	54.87	0.00
Sandford Lock Tail (45.164)	54.58	54.58	0.00	54.58	0.00	54.58	0.00
Minns Estate (47m.26B)	57.40	57.40	0.00	57.40	0.00	57.40	0.00
New Botley (47k.017)	57.58	57.58	0.00	57.58	0.00	57.58	0.00
Cold Harbour (46g.012C)	56.49	56.49	0.00	56.49	0.00	56.49	0.00
Ice Rink (47f.103F)	56.73	56.73	0.00	56.73	0.00	56.73	0.00
Cherwell (CH.014)	56.46	56.46	0.00	56.46	0.00	56.46	0.00

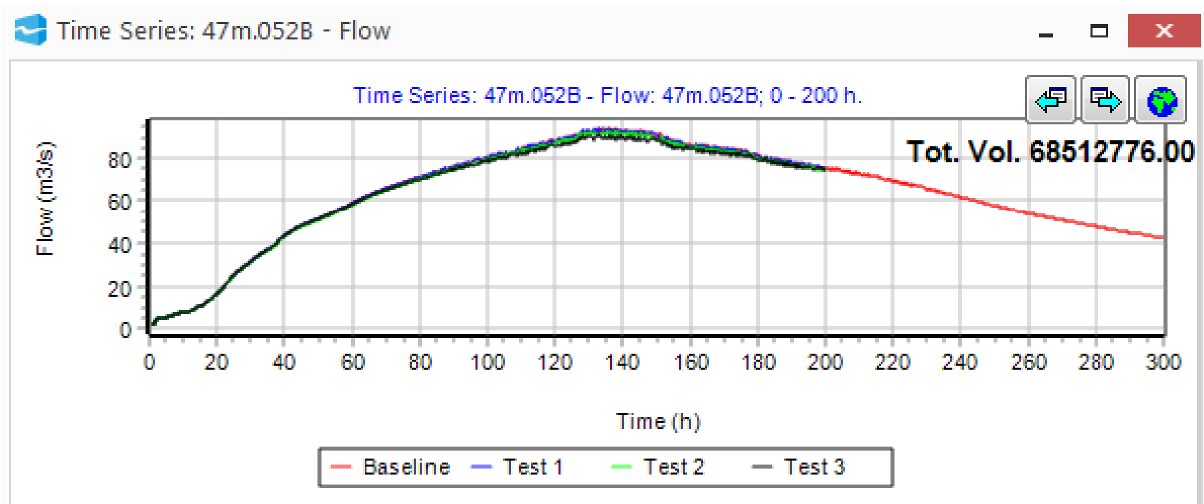


Figure D1: Peer 3 review, flows through A34

Appendix E
Outline Design Model Files

Model File Names

The key model run files for the outline design model are presented in Table D1. Table D2, lists the GIS layers that form the schematisation of the 2D component of the model.

Table E1: Model run files for outline design

File	Model
1D run file	Ox_FAS2Hq_<RP>.ief
1D model file	Ox_FAS_Hq.DAT
1D boundary files	y0_<RP>.IED
2D run file	Ox_FAS2Hq_<RP>.tcf
2D geometry file	Ox_FAS_Design_Hk.tgc
2D boundary file	Ox_FAS_Design_Hk.tbc
2D materials file	Oxford_2D_materials.tmf

Table E2: Description of layers used in the 2D (TUFLOW) model component

Layer	Format	Description
1d_nwk_estry_devils_2B3A4A	Shapefile	ESTRY culvert network for Devils Backbone
1d_FM_node_FAS_Hk	Shapefile	ISIS node locations
2d_iwl_Oxford_polygon	Shapefile	Initial water level in certain areas
2d_iwl_lake_Oxford_polygon	Shapefile	Initial water level set in lakes and Hinksey Stream
2d_po_Oxford	Shapefile	Read PO lines
2d_bc_Ox_FAS_Hk	Shapefile	Sets HX links between 1D channel & 2D domain
2d_bc_sx_FAS_H	Shapefile	Sets SX links for Devils Backbone
2d_bc_sx_Oxford_20121025_GM01	MapInfo	Sets general SX links
2d_zsh_lakebed_Oxford_polygon	Shapefile	Assumed bed levels in lakes
2d_zsh_banks_FAS_Hk_polyline	Shapefile	Sets elevations along river banks at 1D-2D link
2d_zsh_banks_FAS_Hk_point	Shapefile	Sets elevations along river banks at 1D-2D link
2d_zsh_defences_Oxford_polyline	Shapefile	Sets elevations along river banks at 1D-2D link with surveys 11227, 11228, 11230 (dated 2011)
2d_zsh_defences_Oxford_point	Shapefile	Sets elevations along river banks at 1D-2D link with surveys 11227, 11228, 11230 (dated 2011)
2d_zsh_rail_proposed_01_polyline	Shapefile	Network Rail track raising
2d_zsh_rail_proposed_01_point	Shapefile	Network Rail track raising
2d_zsh_FAS_Defences_polyline	Shapefile	Defences for Oxford FAS
2d_zsh_hink_polyline	Shapefile	Hinksey Defences
2d_zsh_Hinksey_Ditch_polyline	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_Hinksey_Ditch_point	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_Hinksey_Ditch_polygon	Shapefile	Sets elevations along Hinksey Ditch
2d_zsh_embankments_Oxford_CH2M_H_polyline	Shapefile	Sets elevations along embankments
2d_zsh_embankments_Oxford_CH2M_H_point	Shapefile	Sets elevations along embankments

Layer	Format	Description
2d_zsh_flowpaths_Oxford_CH2M_H_polyline	Shapefile	Sets elevations along flow paths
2d_zsh_flowpaths_Oxford_CH2M_H_point	Shapefile	Sets elevations along flow paths
2d_mat_stability_v2	Shapefile	Improve stability at Devil's Backbone and Hinksey
2d_code_Ox_FAS_Hk	Shapefile	Sets null cells within river channel
2d_loc_Oxford_20120726_GM01	MapInfo	Defines the SW corner/orientation of the 2D grid
2d_code_Oxford_20120928_GM01	MapInfo	Defines the active 2D cells
2d_zsh_DTMfill_Oxford_20120806_GM01	MapInfo	Areas with no LiDAR data get filled in
2d_zsh_rivers_Oxford_CH2M_E	MapInfo	Sets elevations along river channels
2d_lfcsh_culverts_Oxford_F_polyline	Shapefile	Sets flow constrictions for bridges/culverts along watercourses represented in 2D
2d_mat_manmade_Oxford_20120824_GM0	MapInfo	Define man-made areas
2d_mat_multi_Oxford_20120824_GM01	MapInfo	Define multi-use areas
2d_mat_rail_Oxford_20120824_GM01	MapInfo	Define rail areas
2d_mat_road_Oxford_20120824_GM01	MapInfo	Define roads
2d_mat_path_Oxford_20120824_GM01	MapInfo	Define paths
2d_mat_rough_ground_Oxford_20120824_GM01	MapInfo	Define rough ground areas
2d_mat_scrub_Oxford_20120824_GM01	MapInfo	Define scrub areas
2d_mat_trees_Oxford_20120824_GM01	MapInfo	Define forested areas
2d_mat_water_Oxford_20120824_GM01	MapInfo	Define water bodies
2d_mat_buildings_Oxford_20120824_GM01	MapInfo	Define building areas
Oxford_DTM_merged	ASCII	Reads in the DTM grid

Run Parameters

The model simulations were run in an unsteady state with a 1.5 second 1D time step and a 3 second 2D time step. The 2D horizontal model resolution is 10 metres.

The model parameters in the .ief run file are primarily set to the default values recommended by Flood Modeller. The exceptions are as follows:

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- The **maxitr** parameter is set to 19, which allows the number of iterations per time step for the model to solve the shallow water equations. Performing more iterations increases the probability of model convergence.
- The **Matrix Dummy coefficient** is set to 0.00001, which reduces the probability of the results matrix becoming singular and crashing the model.

Model Outputs

Model results for both the 1D Flood Modeller and 2D Tuflow components are saved at 15-minute intervals, which limits the results file sizes. Outputs from the 2D component include level, flow, velocity, depth, mass balance and UK Hazard results. Time-series level and flow data within the 2D domain are also output at the PO-line locations within the model.

Appendix F
Outline Design Model Results

Table F1: Peak water levels and flows – 20 year

ID	Node	Locations	Peak Water level (mAOD) and Differences (m)			Peak Flow (m^3/s) & Headloss (m) *	
			DM	Option	Diff	DM	Option
1	49.003U	Godstow Weir U/S	58.33	58.33	0.00	56.4	56.4
2	48.085	Godstow Weir D/S	57.97	57.96	-0.01	0.36	0.37
3	48.046	Thames at Castle Mill Stream	57.63	57.61	-0.02	90.9	91.6
4	48.021	Thames at Bulstake Stream	57.36	57.19	-0.17	59.4	61.5
5	47m.083B	Seacourt Stream D/S Thames offtake	59.64	59.64	0.00	8.5	8.5
6	47m.052B	Seacourt Stream A34	57.76	57.74	-0.02	52.7	52.8
7	47m.036B	Seacourt_Stream/Botley Stream	57.40	57.11	-0.29	13.2	17.7
8	SS-01391	Seacourt_Stream - Botley Rd U/S	57.33	56.89	-0.44	25.7	59.7
9	47m.28S	Seacourt_Stream - Botley Rd D/S	57.32	56.76	-0.56	0.01	0.13
10	47k.017	Bulstake Stream - Botley Road U/S	57.17	56.90	-0.27	52.9	37.4
11	BS01.047	Bulstake Stream - Botley Road D/S	57.12	56.87	-0.25	0.05	0.03
12	48.007	Thames - Osney US	56.92	56.73	-0.19	47.0	43.4
13	47f.006A	Castle Mill Stream	57.32	57.16	-0.16	13.9	12.2
14	47r.004	Osney Ditch - Botley Road U/S	57.27	56.96	-0.31	15.6	13.2
15	OD01.004	Osney Ditch - Botley Road D/S	57.04	56.79	-0.25	0.24	0.17
16	47.102	Thames - Osney DS	56.19	56.00	-0.19	102.0	85.0
17	HS2.001	Devils Backbone	56.25	55.98	-0.27	18.8	17.9
18	E-00690b	Hinksey Stream - Railway Bridges U/S	56.19	55.80	-0.38	24.3	15.7
19	E-00676d	Hinksey Stream - Railway Bridges D/S	56.09	55.77	-0.33	0.09	0.04
20	M-00158	Redbridge Stream - Abingdon Road U/S	55.96	55.30	-0.66	4.7	0.4
21	M-00133	Redbridge Stream - Abingdon Road D/S	55.72	55.30	-0.42	0.24	0.00
22	46g.012C	Mayweed Bridge - Abingdon Road U/S	55.98	55.67	-0.31	24.7	25.8
23	P-00327	Mayweed Bridge - Abingdon Road D/S	55.69	55.33	-0.36	0.29	0.34
24	G-00320b	Hinksey Drain - Abingdon Road U/S	56.14	55.70	-0.44	18.6	14.0
25	G-00320	Hinksey Drain - Abingdon Road D/S	55.92	55.57	-0.35	0.22	0.13
26	Q-00177a	Strouds Bridge U/S	55.77	55.50	-0.27	7.3	10.1
27	Q-00156	Strouds Bridge D/S	55.72	55.41	-0.31	0.05	0.09
28	MU01.005	Mundays Bridge U/S	55.15	55.08	-0.07	19.6	49.6
29	46g.001D	Mundays Bridge D/S	55.15	55.06	-0.08	0.01	0.02
30	46g.004C	Hinksey Stream A423 Bypass D/S	55.17	55.13	-0.04	42.4	39.1
31	hin3b6a	Hinksey ditch A423 Bypass D/S	55.28	55.19	-0.09	19.2	49.6
32	46h.070A	Weirs Mill Stream - Donnington Br D/S	55.30	55.21	-0.09	81.8	69.9
33	46h.065A	Weirs Mill Stream	55.23	55.14	-0.09	57.2	51.9
34	EW01.008	Eastwkye Ditch A4144	55.92	55.76	-0.17	6.2	0.3
35	EW01.023	Eastwkye Ditch - Railway Culvert	56.23	56.08	-0.15	11.2	0.7
36	TH47_003	Thames - Iffley Lock U/S	55.54	55.41	-0.13	0.69	0.67
37	46.038	Thames - Iffley Lock D/S	54.95	54.95	0.00	227.1	227.4
38	46.03	Thames - Railway	54.75	54.75	0.00	199.4	199.4
39	45.166	Thames - Rose Isle	53.87	53.87	0.00	0.87	0.87
40	46.002	Thames - Sandford Weir U/S	54.39	54.39	0.00	90.9	90.9
41	45.179	Thames - Sandford Weir D/S	54.04	54.04	0.00	0.35	0.35
42	45.164	Thames - Sandford Lock D/S	53.87	53.87	0.00	193.9	193.8
43	45.128	Thames Outflow	53.54	53.54	0.00	232.0	231.8
44	Ab_culu	New Abingdon Road Channel		55.70			41.6
45	L-00683d	Redbridge Brook D/S Railway	56.06	55.30	-0.75	3.8	0.4
46	CH.014	Cherwell Oxford Gauge	56.08	56.02	-0.07	36.7	37.0

Table F2: Peak water levels and flows – 50 year

ID	Node	Locations	Peak Water level (mAOD) and Differences (m)			Peak Flow (m^3/s) & Headloss (m) *	
			DM	Option	Diff	DM	Option
1	49.003U	Godstow Weir U/S	58.41	58.41	0.00	59.0	58.9
2	48.085	Godstow Weir D/S	58.04	58.01	-0.02	0.37	0.40
3	48.046	Thames at Castle Mill Stream	57.71	57.65	-0.07	97.1	99.1
4	48.021	Thames at Bulstake Stream	57.46	57.26	-0.20	59.6	61.7
5	47m.083B	Seacourt Stream D/S Thames offtake	59.68	59.68	0.00	8.6	8.6
6	47m.052B	Seacourt Stream A34	57.84	57.81	-0.03	61.7	61.9
7	47m.036B	Seacourt_Stream/Botley Stream	57.50	57.26	-0.24	13.4	17.7
8	SS-01391	Seacourt_Stream - Botley Rd U/S	57.44	57.09	-0.34	28.1	70.6
9	47m.28S	Seacourt_Stream - Botley Rd D/S	57.42	56.92	-0.51	0.01	0.18
10	47k.017	Bulstake Stream - Botley Road U/S	57.26	57.04	-0.22	59.3	45.3
11	BS01.047	Bulstake Stream - Botley Road D/S	57.20	57.00	-0.20	0.06	0.04
12	48.007	Thames - Osney US	57.03	56.82	-0.21	51.4	43.4
13	47f.006A	Castle Mill Stream	57.43	57.23	-0.20	15.1	12.9
14	47r.004	Osney Ditch - Botley Road U/S	57.39	57.14	-0.26	15.8	14.7
15	OD01.004	Osney Ditch - Botley Road D/S	57.16	56.93	-0.23	0.23	0.21
16	47.102	Thames - Osney DS	56.31	56.15	-0.16	113.3	94.9
17	HS2.001	Devils Backbone	56.39	56.17	-0.22	19.0	18.1
18	E-00690b	Hinksey Stream - Railway Bridges U/S	56.34	56.04	-0.30	24.4	19.5
19	E-00676d	Hinksey Stream - Railway Bridges D/S	56.26	55.97	-0.29	0.08	0.07
20	M-00158	Redbridge Stream - Abingdon Road U/S	56.07	55.48	-0.59	4.8	1.5
21	M-00133	Redbridge Stream - Abingdon Road D/S	55.86	55.46	-0.40	0.22	0.02
22	46g.012C	Mayweed Bridge - Abingdon Road U/S	56.18	55.90	-0.28	27.3	29.3
23	P-00327	Mayweed Bridge - Abingdon Road D/S	55.83	55.48	-0.35	0.35	0.42
24	G-00320b	Hinksey Drain - Abingdon Road U/S	56.29	55.95	-0.34	20.5	16.5
25	G-00320	Hinksey Drain - Abingdon Road D/S	56.03	55.77	-0.26	0.26	0.18
26	Q-00177a	Strouds Bridge U/S	55.89	55.70	-0.19	7.4	12.5
27	Q-00156	Strouds Bridge D/S	55.88	55.56	-0.32	0.02	0.14
28	MU01.005	Mundays Bridge U/S	55.32	55.28	-0.04	23.1	56.4
29	46g.001D	Mundays Bridge D/S	55.28	55.19	-0.10	0.04	0.09
30	46g.004C	Hinksey Stream A423 Bypass D/S	55.31	55.26	-0.05	47.5	46.4
31	hin3b6a	Hinksey ditch A423 Bypass D/S	55.45	55.39	-0.06	21.3	57.3
32	46h.070A	Weirs Mill Stream - Donnington Br D/S	55.45	55.33	-0.12	88.2	79.7
33	46h.065A	Weirs Mill Stream	55.38	55.28	-0.11	57.4	50.7
34	EW01.008	Eastwkye Ditch A4144	56.02	55.90	-0.12	6.5	0.3
35	EW01.023	Eastwkye Ditch - Railway Culvert	56.34	56.24	-0.10	13.8	0.7
36	TH47_003	Thames - Iffley Lock U/S	55.65	55.55	-0.10	0.69	0.69
37	46.038	Thames - Iffley Lock D/S	55.06	55.06	0.00	259.1	258.7
38	46.03	Thames - Railway	54.84	54.83	0.00	221.7	221.1
39	45.166	Thames - Rose Isle	54.03	54.03	0.00	0.81	0.81
40	46.002	Thames - Sandford Weir U/S	54.48	54.48	0.00	94.6	94.4
41	45.179	Thames - Sandford Weir D/S	54.20	54.20	0.00	0.28	0.28
42	45.164	Thames - Sandford Lock D/S	54.03	54.03	0.00	213.2	212.7
43	45.128	Thames Outflow	53.71	53.70	0.00	265.3	264.3
44	Ab_culu	New Abingdon Road Channel		55.94			47.4
45	L-00683d	Redbridge Brook D/S Railway	56.16	55.51	-0.66	3.9	1.5
46	CH.014	Cherwell Oxford Gauge	56.17	56.11	-0.06	40.9	41.1

Table F3: Peak water levels and flows – 1000 year

ID	Node	Locations	Peak Water level (mAOD) and Differences (m)			Peak Flow (m^3/s) & Headloss (m) *	
			DM	Option	Diff	DM	Option
1	49.003U	Godstow Weir U/S	58.87	58.86	-0.01	69.9	69.9
2	48.085	Godstow Weir D/S	58.22	58.20	-0.02	0.65	0.66
3	48.046	Thames at Castle Mill Stream	57.95	57.91	-0.04	115.5	120.2
4	48.021	Thames at Bulstake Stream	57.76	57.66	-0.10	59.6	62.0
5	47m.083B	Seacourt Stream D/S Thames offtake	59.84	59.84	0.00	8.9	8.9
6	47m.052B	Seacourt Stream A34	58.11	58.07	-0.04	93.9	92.9
7	47m.036B	Seacourt_Stream/Botley Stream	57.81	57.70	-0.11	15.2	18.4
8	SS-01391	Seacourt_Stream - Botley Rd U/S	57.74	57.56	-0.18	33.4	95.1
9	47m.28S	Seacourt_Stream - Botley Rd D/S	57.69	57.27	-0.42	0.05	0.28
10	47k.017	Bulstake Stream - Botley Road U/S	57.58	57.43	-0.15	77.1	73.0
11	BS01.047	Bulstake Stream - Botley Road D/S	57.42	57.32	-0.10	0.17	0.11
12	48.007	Thames - Osney US	57.36	57.22	-0.14	65.0	61.6
13	47f.006A	Castle Mill Stream	57.72	57.62	-0.10	20.1	18.3
14	47r.004	Osney Ditch - Botley Road U/S	57.70	57.60	-0.10	15.9	15.7
15	OD01.004	Osney Ditch - Botley Road D/S	57.49	57.38	-0.11	0.22	0.23
16	47.102	Thames - Osney DS	56.65	56.59	-0.06	142.7	140.3
17	HS2.001	Devils Backbone	56.69	56.65	-0.04	19.2	19.0
18	E-00690b	Hinksey Stream - Railway Bridges U/S	56.64	56.57	-0.07	25.7	26.5
19	E-00676d	Hinksey Stream - Railway Bridges D/S	56.54	56.44	-0.09	0.10	0.13
20	M-00158	Redbridge Stream - Abingdon Road U/S	56.42	56.26	-0.16	4.7	5.3
21	M-00133	Redbridge Stream - Abingdon Road D/S	56.23	55.97	-0.26	0.19	0.29
22	46g.012C	Mayweed Bridge - Abingdon Road U/S	56.49	56.40	-0.09	28.5	34.1
23	P-00327	Mayweed Bridge - Abingdon Road D/S	56.18	55.93	-0.26	0.31	0.48
24	G-00320b	Hinksey Drain - Abingdon Road U/S	56.60	56.52	-0.07	22.6	21.7
25	G-00320	Hinksey Drain - Abingdon Road D/S	56.29	56.24	-0.05	0.31	0.29
26	Q-00177a	Strouds Bridge U/S	56.20	56.17	-0.03	7.3	16.0
27	Q-00156	Strouds Bridge D/S	56.21	55.95	-0.26	-0.01	0.22
28	MU01.005	Mundays Bridge U/S	55.86	55.79	-0.07	33.6	69.4
29	46g.001D	Mundays Bridge D/S	55.80	55.68	-0.12	0.07	0.12
30	46g.004C	Hinksey Stream A423 Bypass D/S	55.80	55.71	-0.09	57.9	60.7
31	hin3b6a	Hinksey ditch A423 Bypass D/S	55.99	55.89	-0.09	23.6	69.4
32	46h.070A	Weirs Mill Stream - Donnington Br D/S	56.02	55.90	-0.12	97.6	86.3
33	46h.065A	Weirs Mill Stream	55.97	55.86	-0.11	67.1	60.7
34	EW01.008	Eastwkye Ditch A4144	56.37	56.28	-0.08	6.9	3.7
35	EW01.023	Eastwkye Ditch - Railway Culvert	56.68	56.70	0.02	16.2	0.7
36	TH47_003	Thames - Iffley Lock U/S	56.01	55.91	-0.10	0.67	0.80
37	46.038	Thames - Iffley Lock D/S	55.48	55.49	0.00	379.9	382.7
38	46.03	Thames - Railway	55.20	55.21	0.01	299.1	300.3
39	45.166	Thames - Rose Isle	54.58	54.59	0.01	0.62	0.62
40	46.002	Thames - Sandford Weir U/S	54.85	54.85	0.01	117.3	117.5
41	45.179	Thames - Sandford Weir D/S	54.75	54.76	0.01	0.09	0.09
42	45.164	Thames - Sandford Lock D/S	54.58	54.59	0.01	271.4	272.2
43	45.128	Thames Outflow	54.28	54.28	0.01	393.3	395.0
44	Ab_culu	New Abingdon Road Channel		56.49			58.4
45	L-00683d	Redbridge Brook D/S Railway	56.48	56.31	-0.17	5.0	3.6
46	CH.014	Cherwell Oxford Gauge	56.46	56.40	-0.06	56.7	56.6