East West Rail Phase 2

EWR Alliance

Flood Risk Assessment: CFSA Modelling Report (Langford Brook)

CFSA ID: 2A0061/5.2/FH

NGR: 460286, 223307

Section: 2A

Discipline/Grip Stage: Drainage Culverts / GRIP 5

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EWR Alliance

East West Rail Phase 2

Langford Brook

CFSA Modelling Report

August 2020

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Executive Summary

This report sets out the hydrological and hydraulic modelling approach adopted to assess the potential flood risk effects of the East West Rail Phase 2 project (EWR2) on Route Section 2A, north-east of Bicester at National Grid Reference (NGR) 460286, 223307, on the Langford Brook. This report is submitted to discharge Planning Condition 13 and is submitted in line with the Planning Condition 13 Phasing Strategy, and is located in development stage 2A1.

The existing Environment Agency Langford Brook hydrological and hydraulic model has been improved and used to assess flood risk to EWR2, the potential impacts of the Scheme and compensation options. The potential impacts of climate change were assessed by increasing flows by 70%.

An assessment of the temporary floodplain losses arising from the temporary Charbridge Lane diversion works, temporary construction storage along with an assessment of the permanent floodplain volume losses arising from railway earthworks and highway overbridge works has been undertaken.

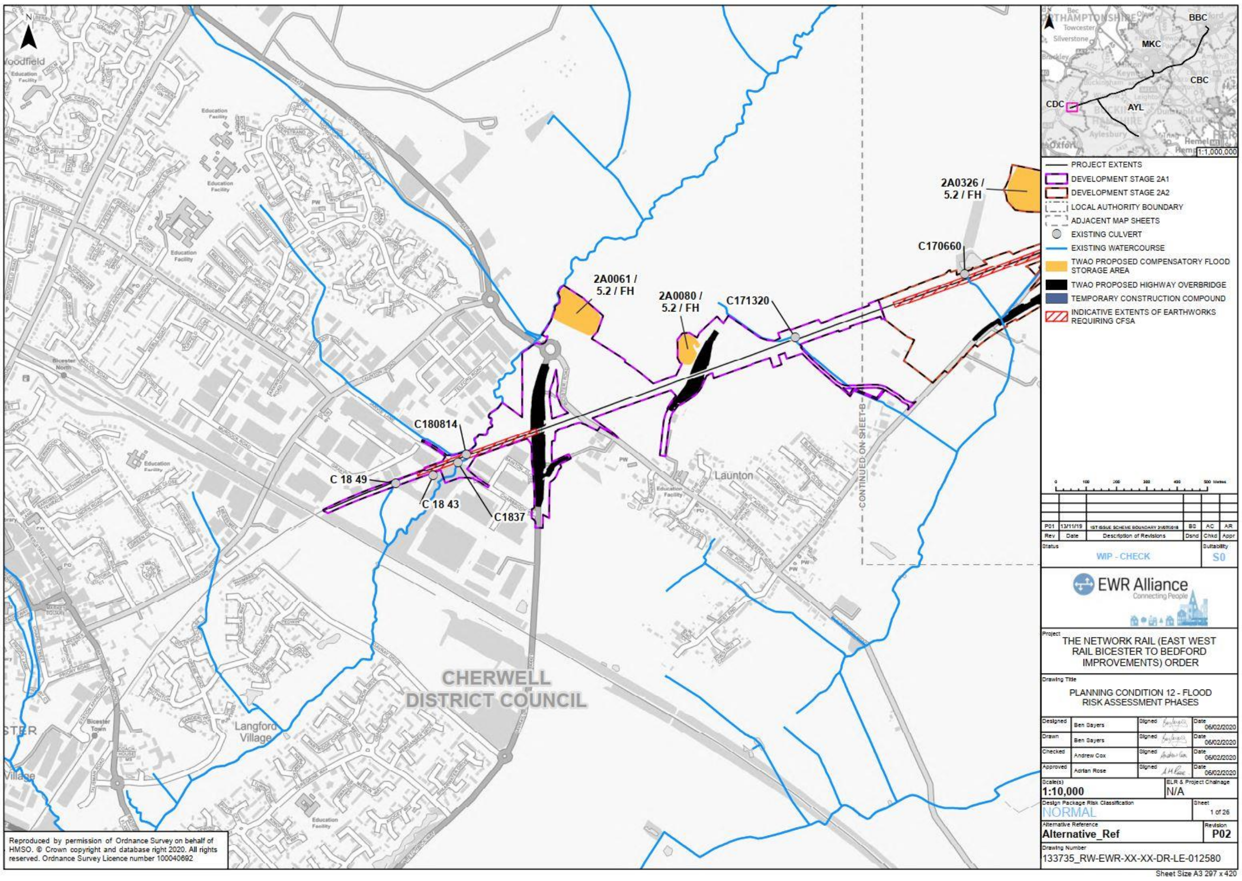
The hydrological and hydraulic model has been updated to include the combined (permanent and temporary) With Scheme proposal and used to size the proposed CFSA. The proposed CFSA has been designed to compensate for the combined temporary and permanent works in line with CIRIA 624 and provides a total floodplain volume of 2287m^3. The CFSA will be in place prior to any ground raising or storage works in the floodplain being undertaken.

The CFSA mitigates for both the temporary and permanent works. Once construction is complete and the temporary works are removed from the floodplain there will be an additional floodplain storage volume >2000m^3 provided by the Scheme under the permanent scenario, and an overprovision during the temporary and permanent scenario of >800m^3. There is therefore a catchment betterment provided by the Scheme.

1. Introduction

This report sets out the hydrological and hydraulic modelling approach adopted to assess the potential flood risk effects of the East West Rail Phase 2 project (EWR2) on Route Section 2A, north-east of Bicester at National Grid Reference (NGR) 460286, 223307, on the Langford Brook. This report is submitted to discharge Planning Condition 13 and is submitted in line with the Planning Condition 13 Phasing Strategy for assets C180814, Charbridge Lane Road Overbridge (OXD/36AA), new backwater channel, temporary construction works and railway earthworks associated with Compensatory Flood Storage Area (CFSA) 2A0261/5.2/FH, and is located in development stage 2A1. The figure below shows the Phasing Strategy submission for this area.

Figure 1-1 Planning Condition 13 Phasing Strategy



Placing structures in the floodplain takes up space where floodwaters should flow or be stored and therefore results in a loss of floodplain storage. In order to ensure the risk of flooding is not increased elsewhere, where the consequences may be more severe, floodplain compensation is necessary. This is where new areas of land, in close proximity to the area of floodplain loss, are lowered to compensate for that loss. Compensatory Flood Storage Areas (CFSAs) should preferably be located on the edge of the floodplain, but need to be hydraulically connected, so water can flow or be stored in the compensation areas during times of flooding.

The location and maximum extent of the CFSAs were identified in the Flood Risk Assessment (FRA) and Environmental Statement (ES).

Objectives

This report sets out the location of the floodplain loss and CFSAs; the methods used to calculate losses and gains in the floodplain for earthworks associated with railway embankment improvements and Charbridge Lane Road Overbridge (OXD/36AA). The objectives of this assessment and report are as follows:

- To develop a hydrological and hydraulic model of the river channel and floodplain system to understand potential flood risk mechanisms more clearly;
- To test and inform the design of the earthworks, temporary works, culvert works and CFSA works to ensure risks to EWR2 and receptors upstream and downstream are understood, including an allowance for climate change; and
- Document this work and seek approval from the regulator, in this case the Environment Agency.

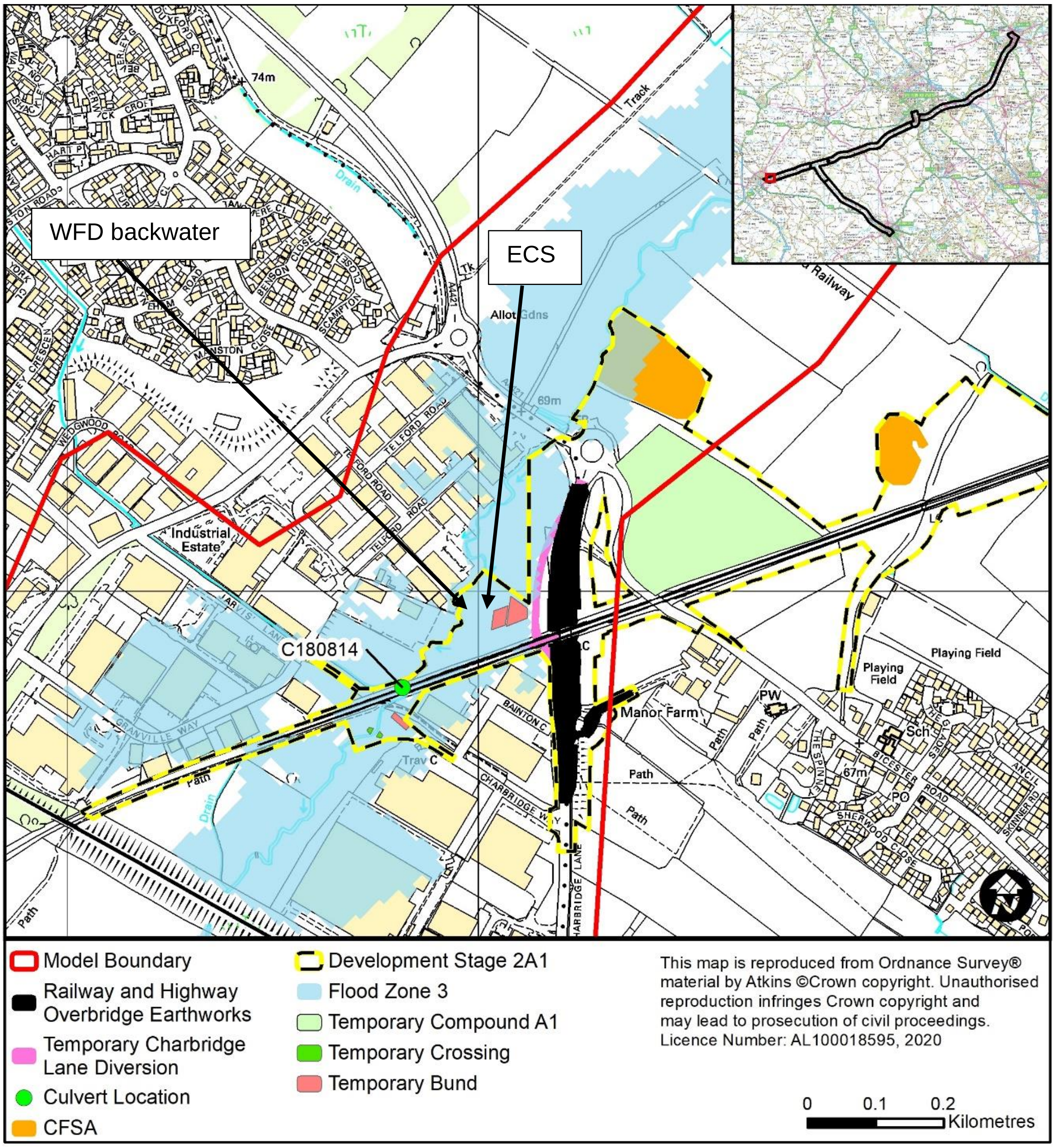
Site Description

The study area is located north-east of Bicester on Route Section 2A, adjacent Charbridge Lane Overbridge (OXD/36AA). The LLFA is Oxfordshire County Council (OCC) and the site falls within the Thames River Basin District. It is a rural setting to the north and east of the EWR2 route but is on the outskirts of the town of Bicester to the south and west. EWR2 is on embankment in this reach. Flood risk in this area is from the Langford Brook, which flows from north to south through the existing EWR2 route. The Langford Brook is defined as a Main River in this reach. There is an existing culvert (C180814, brick arch culvert) which conveys the Langford Brook through the EWR2 route.

There is extensive existing fluvial flooding in this area affecting both banks throughout the study reach. Assets within the floodplain are Network Rail land, parts of the road network, agricultural land and a number of properties in Bicester and the industrial area in the eastern extent of the town.

The figure below displays the site location, key features and Environment Agency flood outlines.

Figure 1-2 Site Location



EWR2 Scheme

At this site the following EWR2 works are proposed which are considered as part of this assessment:

- New highway overbridge (OXD/36AA Charbridge Lane);
- Temporary Construction Compound A1 (in place for no more than 5-years);
- Temporary construction storage and haul road (in place for 12-18 months);
- Temporary watercourse crossing (in place for 12 months);
- Temporary highway diversion of Charbridge Lane (in place for between 12-14 months);

- Creation of a permanent backwater on the left bank of the Langford Brook as part of the Water Framework Directive mitigation works, approximately 160m upstream of culvert C180814;
- Improvements to the railway embankment earthworks (localised re-grades);
- Jarvis Lane footbridge;
- Ecological Compensation Site (ECS) A1 (which includes ecological ponds, woodland planting, otter holt), located north of the EWR2 line;
- A CFSA (2A0261/5.2/FH) proposed to mitigate the potential loss of floodplain due to planned permanent and temporary earthworks; and
- Liner rehabilitation to culvert C180814.

Previous Work

The following documents / assessments have been used to inform this modelling study:

- A Flood Risk Mapping Study of Langford Village and Bicester was undertaken by Peter Brett Associates (PBA) in December 2009 (Project Ref 15945/006) on behalf of the Environment Agency, Thames Region (West Area);
- Project Wide Flood Risk Assessment (FRA, reference: The Network Rail (East West Rail Bicester to Bedford Improvements) Order, Environmental Statement, Volume 3, Appendix 13.1, July 2018); and
- Drainage Strategy (reference: The Network Rail (East West Rail Bicester to Bedford Improvements) Order, Environmental Statement, Volume 3, Appendix 13.1H, July 2018).

2. Method

Data

The table below sets out the data that was available and applied in developing the hydrological and hydraulic model for this site.

Table 2-1 Key Data Sources

Data Name	Description
Topographic Survey	Topographic survey of the culvert, channel and CFSA is available. The hydraulic model is predominantly based on topographic survey collected by PBA. Additional topographic survey was collected in August 2019 to check and supplement the existing survey data, and the model updated with recent LiDAR data with an improved model resolution adjacent EWR2 and for the proposed CFSA.
LiDAR	A combination of LiDAR flown for the project at 0.2m resolution and 1m data downloaded from gov.uk available. There is very little difference in elevation (generally less than +/-0.1m) between the 2 datasets.
Culvert site photos	Available for all of the culverts.
Other	The main source of information for this assessment was the existing Environment Agency approved hydrological and hydraulic model.

Sensitivity

The improved Langford Brook hydrological and hydraulic model was subject to extensive sensitivity testing, which has been discussed with the Environment Agency in July 2020; details of the sensitivity tests are reported on in Appendix F.

Scenarios

A range of scenarios were simulated in the hydrological and hydraulic model; these are set out in the table below.

Table 2-2 Model Scenarios

Scenario Number	Description
1	Updated Baseline Model
2	With Scheme Temporary and Permanent works - railway earthworks, Charbridge Lane overbridge and temporary diversion, construction temporary storage in the floodplain (including temporary crossing of the Langford Brook), WFD backwater, culvert liner and proposed CFSA.

Scenario Number	Description
3	Permanent works only - CFSA, the railway embankment earthworks, the permanent Charbridge Lane Overbridge, WFD backwater and the proposed culvert liner.

CFSA Approach

Overview

As described above compensatory flood storage works are required where the Project would otherwise reduce the available volume of flood storage.

CIRIA 624 (Development and flood risk – guidance for the construction industry - Section A.3.3.10, 2004) states that:

"*compensatory flood storage must become effective at the same point in a flood event as the lost storage would have done (McPherson 2002). It should therefore provide the same volume, and be at the same level relative to flood level, as the lost storage. This requirement is often referred to as "level for level" or "direct" compensation".*

Therefore, CIRIA 624 classes level for level based on a flood frequency approach as direct level for level compensation. Where absolute level of level is not possible i.e. where the CFSA cannot be sited in the immediate vicinity of the loss the CIRIA approach will be adopted. This approach was discussed and agreed with the Environment Agency at a meeting 23/10/2018.

The Environment Agency preference is that the CFSA should expand rather than lower the existing floodplain, therefore only areas on the edge of the maximum design flood extent were considered for compensation. Each CFSA connects hydraulically to the watercourse. The flood frequency/volume relationship defines the level at which a specific volume of storage needs to be provided based on a flood frequency approach.

GRIP5 Approach

This approach assesses the frequency of flooding to then apply a level-for-level assessment as described above in CIRIA 624:

- The hydraulic model will be used to calculate the volume lost for a range of return periods;
- Volumes for each flood frequency band will be calculated, giving a frequency volume relationship;
- The threshold of flooding for these return periods will be calculated at the proposed CFSA site and the corresponding volumes provided for each return period;
- A CAD/GIS approach will be used to shape the storage area; and
- This shape will be incorporated into the hydraulic model and run for a range of return periods.

The CFSA will be designed to replace the lost floodplain volume associated with the EWR2 permanent and temporary works.

Langford Brook CFSA

The proposed Langford Brook CFSA is located approximately 500m north east of the railway embankment loss, and approximately 175m north east of the temporary highway diversion floodplain loss. In order to locate the CFSA upstream of the loss area, avoid existing floodplain areas and utilities, this was the closest available location for the CFSA. The CFSA will drain back into Langford Brook by virtue of excavated ground levels. The CFSA will compensate for both the temporary and permanent losses of the proposed works.

The topography slopes up from the loss location to the CFSA with ground levels ranging from 68m AOD to 70.2m AOD at the proposed CFSA location.

3. Baseline Modelling

Overview

A Flood Risk Mapping Study of Langford Village and Bicester was undertaken by Peter Brett Associates (PBA) in December 2009 (Project Ref 15945/006) on behalf of the Environment Agency, Thames Region (West Area). This study included the Langford Brook. This model has been amended following review comments from the Environment Agency and used as the updated baseline model. The updated baseline model has been modified to test the proposed EWR2 scheme and associated compensation measures at the Langford Brook.

Hydrology

The existing PBA (2009) hydrology was reviewed and the flows compared to estimates using new data and methods (including Flood Estimation Handbook (FEH) 2013 data, Revitalised Flood Hydrograph 2 (ReFH2), WINFAP4 and an updated Annual Maximum (AMAX) series. The Alliance recalculated the flows for the Langford Brook using the most current methods and data available (WINFAP4 using peak flow data to October 2018, ReFH2 and ReFH). The flows generated from this assessment were lower than the existing PBA (2009) estimates; the FEH calculation record setting out this detail is provided in Appendix E.

It was proposed and agreed with the Environment Agency (see email from Clark Gordon dated 23/05/2019, provided in Appendix C) that for EWR2 the project would use the existing PBA (2009) flows because these are the most conservative, and therefore provides a precautionary assessment of flood risk.

As a result no changes to the existing hydrology have been made, aside from to apply the latest available climate change allowance. The following flood events were simulated in the model:

- 20% annual chance event;
- 5% annual chance event;
- 2% annual chance event;
- 1% annual chance event;
- 1% annual chance event plus climate change (70% flow in line with guidance from https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances); and
- 0.1% annual chance event.

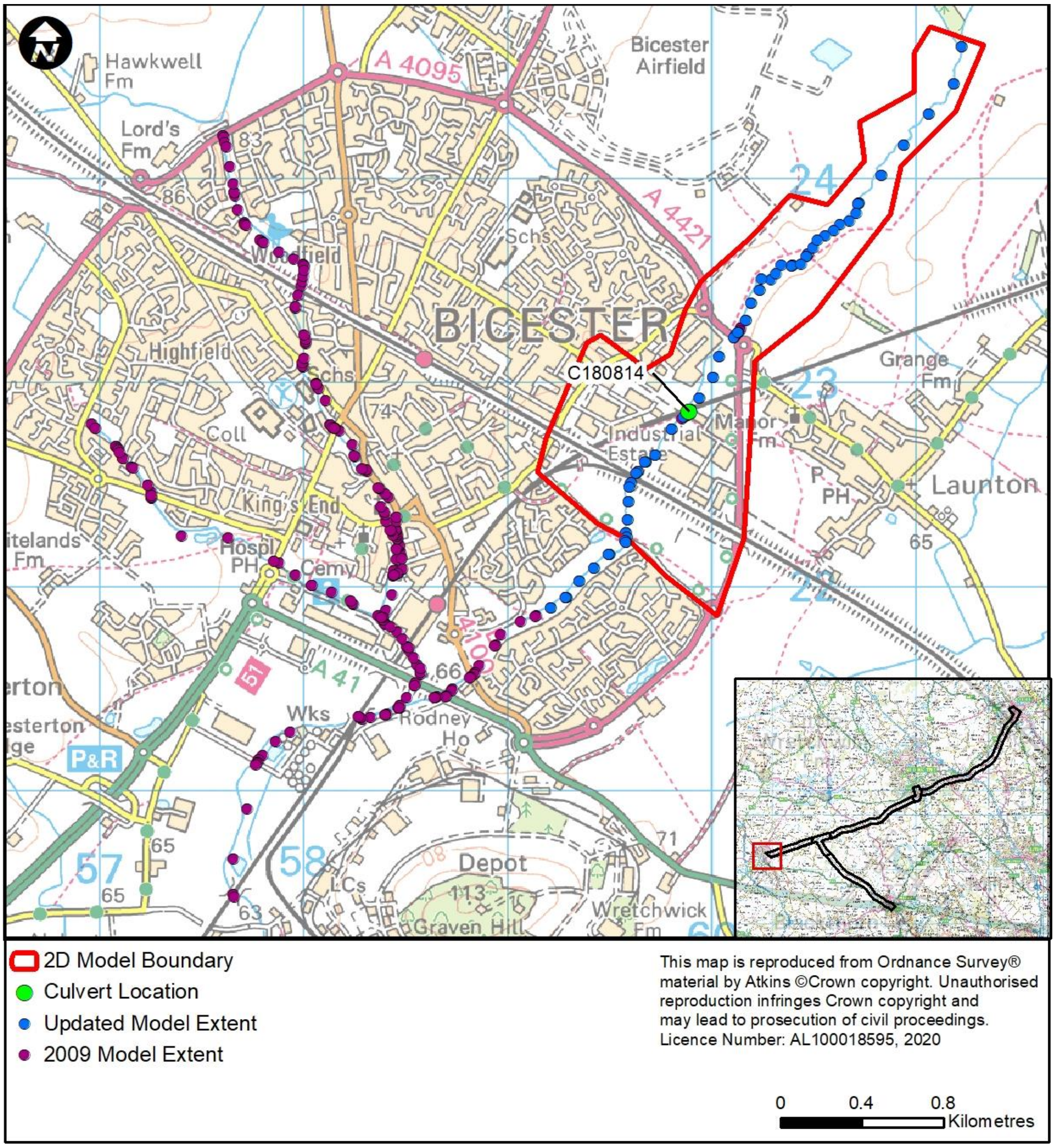
Updated Hydraulic model

Following Environment Agency review comments on the baseline hydraulic model a number of improvements to the model have been undertaken to address these comments, and the baseline model was re-submitted to the Environment Agency on the 13th July 2020. Further detail is provided in Appendix F, with the key improvements being:

- The model cell size changed to 2m throughout the model domain;
- The model extent has been truncated upstream of Gavray Road to focus on the area of interest (see figure below) with a short 1D section downstream of this leading to the downstream boundary;
- The double precision solver has been applied to remove the majority of bank Mass Balance errors;
- The model timestep has been reduced as requested by the Environment Agency;
- Inclusion of more recent topographical data including the EWR2 0.2m LiDAR; and
- Assessed a range of sensitivity tests to demonstrate negligible impact of data uncertainties.

The figure below illustrates the updated hydraulic model extents, demonstrating a reduced model area which focuses on the key areas of interest.

Figure 3-1 Updated hydraulic model extent



Critical Storm Duration

The changes in the hydraulic model have not changed the critical storm duration which is consistent with the original PBA (2009) model at 17.5-hours.

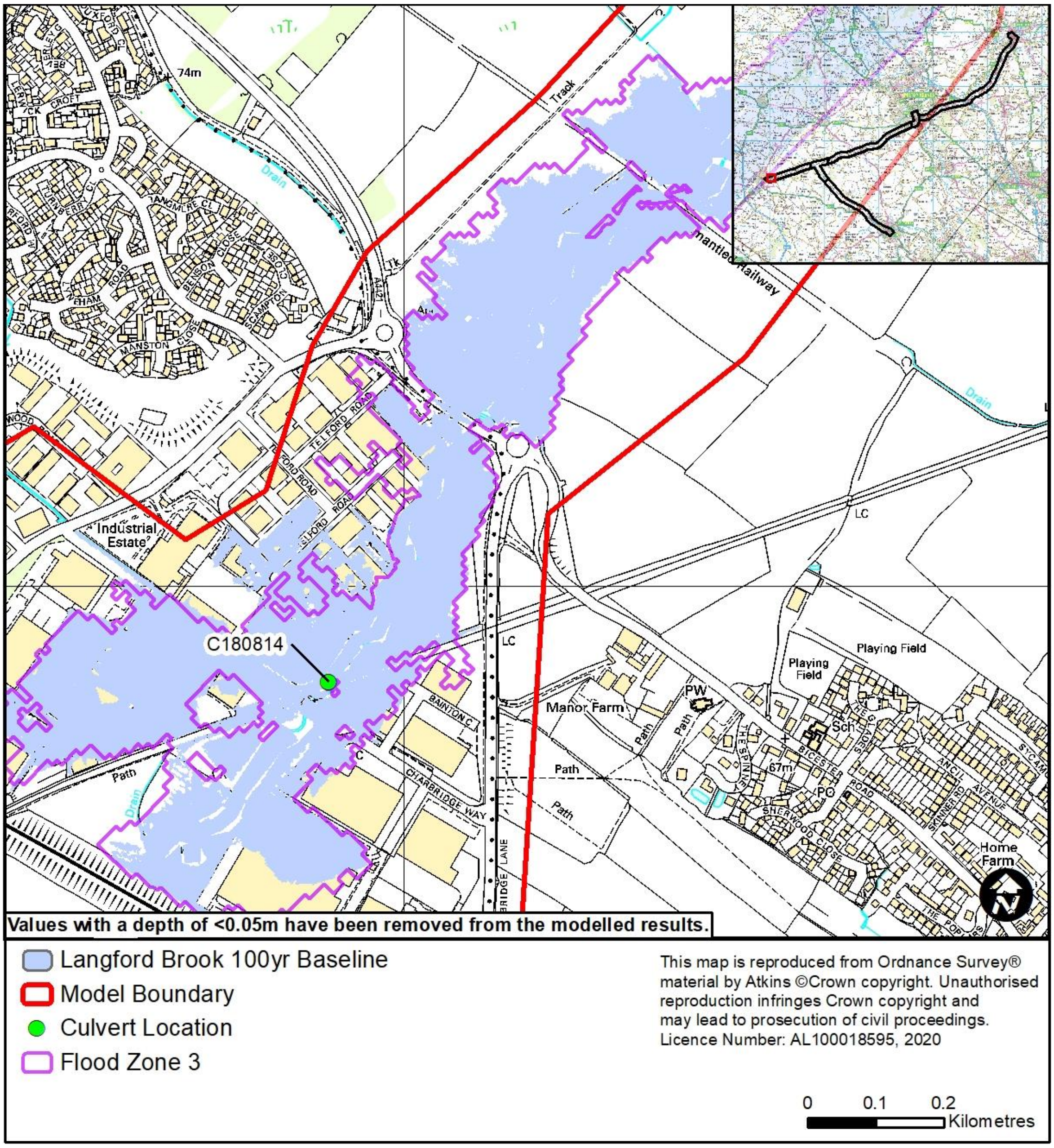
Verification

A detailed comparison of the model outputs between the 2009 Environment Agency model and the updated baseline incorporating Environment Agency review comments can be found in Appendix F.

Existing Flood Outlines

The incoming model has been provided by the Environment Agency as calibrated and verified to historical events. The updates to the baseline hydraulic model have increased the resolution of the topography therefore providing a finer delineation of the flood outline, and improved the performance of the model as set out in Appendix F. As noted above the hydrology used in the 2009 modelling and this study are the same. Whilst the updated model shows some areas with greater flooding and others with less, the general trend of flooding remains similar throughout the study area. The model results have been compared with the Environment Agency Flood Zone 3, as shown in the figure below.

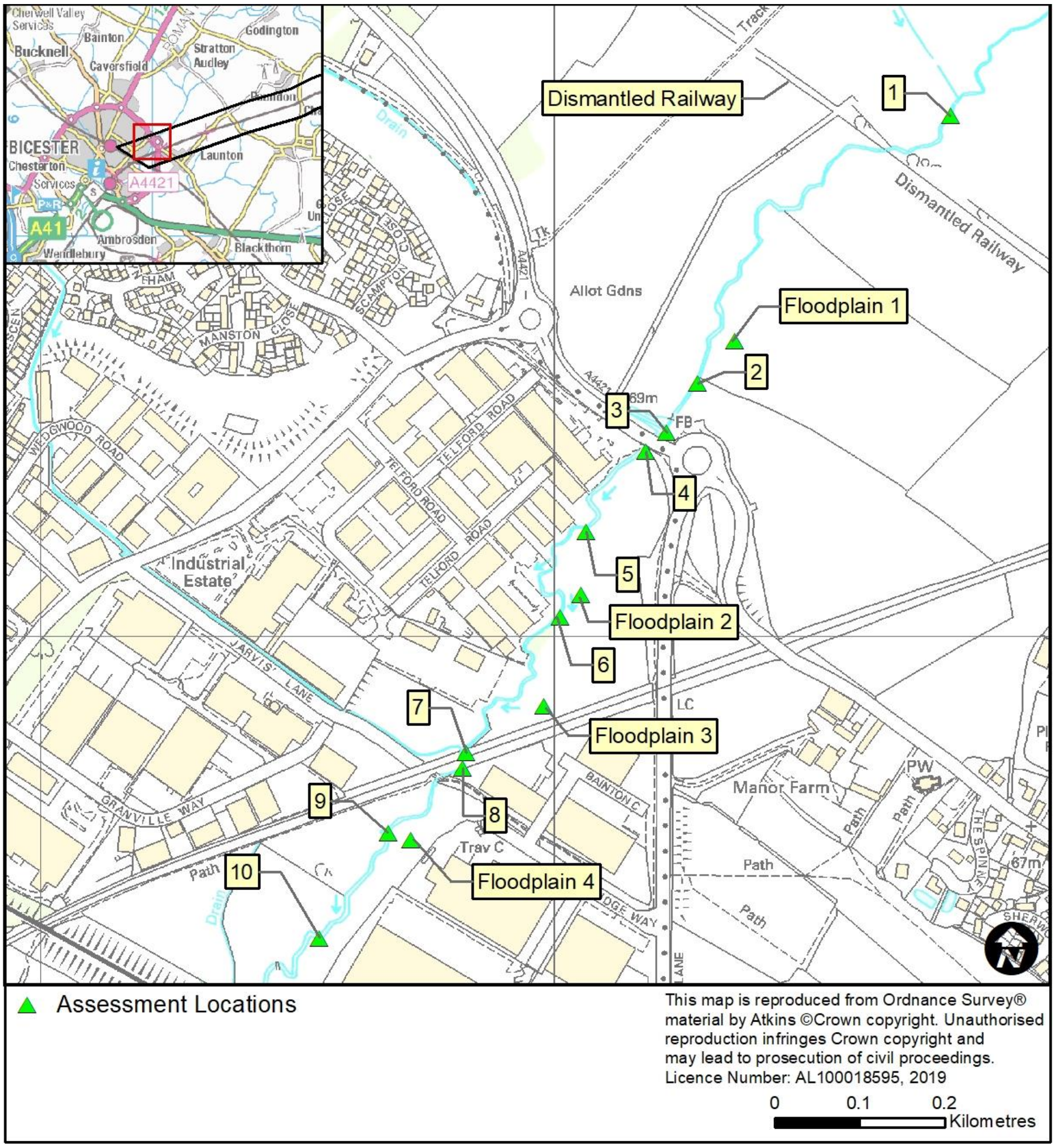
Figure 3-2 Comparison of Flood Zones and modelled 1% annual chance event



Comparison with Environment Agency baseline

A selection of key assessment points have been defined to compare the original Environment Agency baseline results and the updated baseline, these locations are shown in the figure below.

Figure 3-3 Key Assessment Point Locations



The updated baseline peak water levels are compared with the Environment Agency original baseline model in the table below. This shows minor changes in peak water levels with the exception of the cross section upstream of the dismantled railway (LA.5098), assessment point 1, where there is a 0.16m reduction at the 1% annual chance event in the updated baseline, and upstream of the existing EWR2 line (assessment point 6) where there is a 0.12m increase. This increase in baseline flood level is as a result of the increase in model resolution and better representation of the existing dismantled railway embankment.

Table 3-1 Peak Water Level Comparison Environment Agency Baseline model and Updated Baseline model (1% annual chance event)

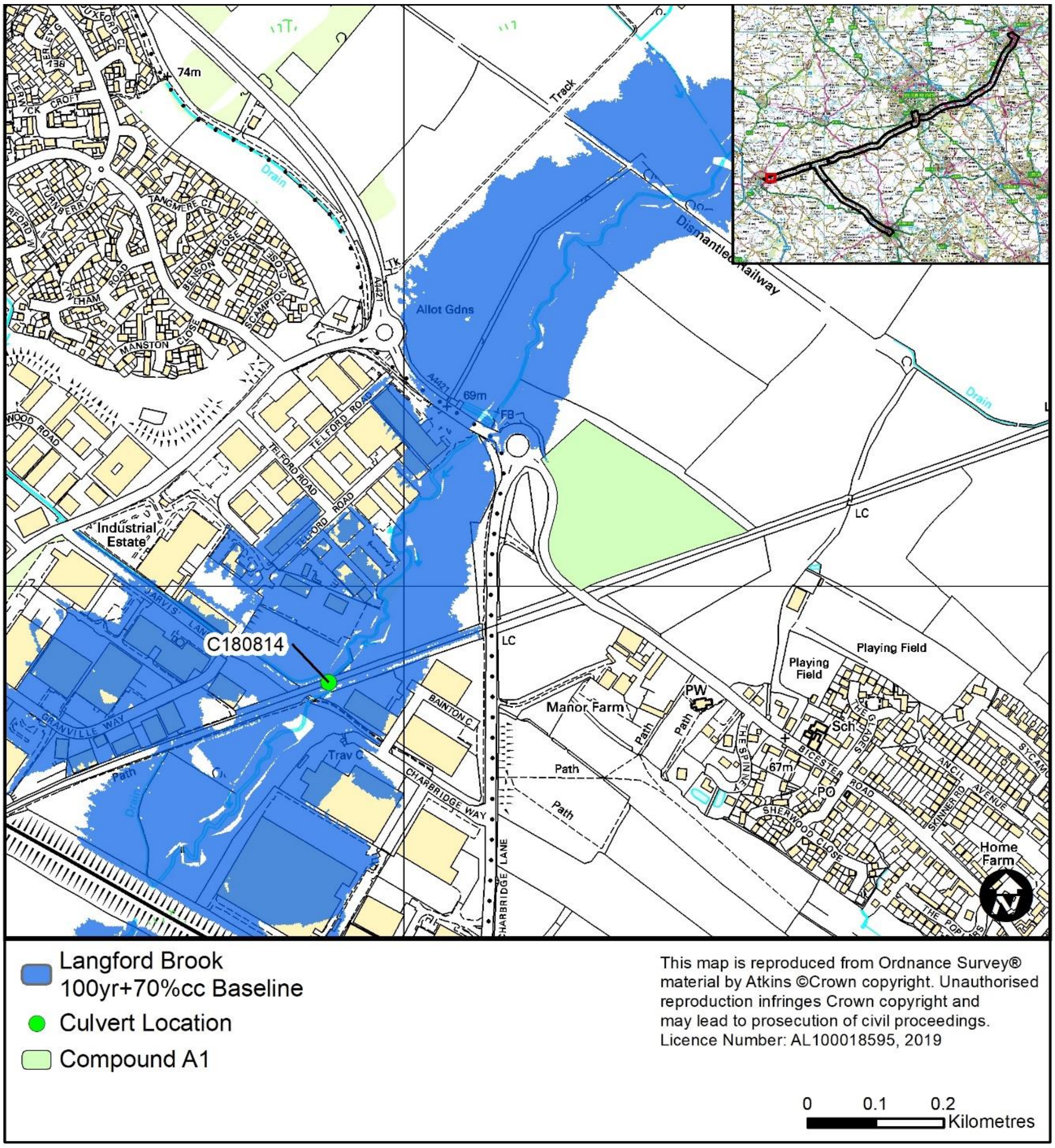
Assessment Point	Location Description	1% annual chance event Peak Water Level EA Baseline (m AOD)	1% annual chance event Peak Water Level Updated Baseline (m AOD)	Difference (m)
1	Upstream of dismantled railway (LA.5098)	70.17	70.02	-0.16
Floodplain 1	Floodplain adjacent to CFSA	69.63	69.59	-0.04
2	Proposed CFSA (LA.4560)	N/A (Baseline has no sections in 481m reach)	69.59	n/a
3	Upstream of Bicester Road A4421 (LA.4493)	69.54	69.57	0.03
4	Downstream of Bicester Road A4421 (LA4458)	69.27	69.30	0.03
5	Adjacent to Telford Road (LA.4323)	69.20	69.29	0.09
Floodplain 2	Floodplain adjacent to temporary works	69.18	69.29	0.11
6	200m upstream of EWR2 culvert (LA.4157)	69.17	69.29	0.12
Floodplain 3	Floodplain adjacent to soil storage	69.17	69.29	0.12
7	Directly upstream of EWR2 route (LA.3919)	69.16	69.27	0.11
8	Directly downstream of EWR2 route (LA.3894)	68.27	68.21	-0.06
9	100m downstream EWR2 (LA.3764)	67.86	67.89	0.03
Floodplain 4	Floodplain downstream of EWR2	67.88	67.92	0.04
10	200m downstream EWR2 (LA.3597)	67.66	67.57	-0.09

Floodplain Storage Loss Assessment

The ECS located north of the EWR2 line includes excavated ponds. The material excavated to construct these ponds will be permanently removed from the site, therefore these works do not require floodplain compensation.

The layout of temporary Compound A1 has been adjusted to avoid floodplain areas and is now located entirely outside of the 1% annual chance event including climate change (70%) floodplain; therefore, no compensation is required for the Compound, this is shown in the following figure.

Figure 3-4 Compound A1 Boundary and 1% annual chance event including climate change

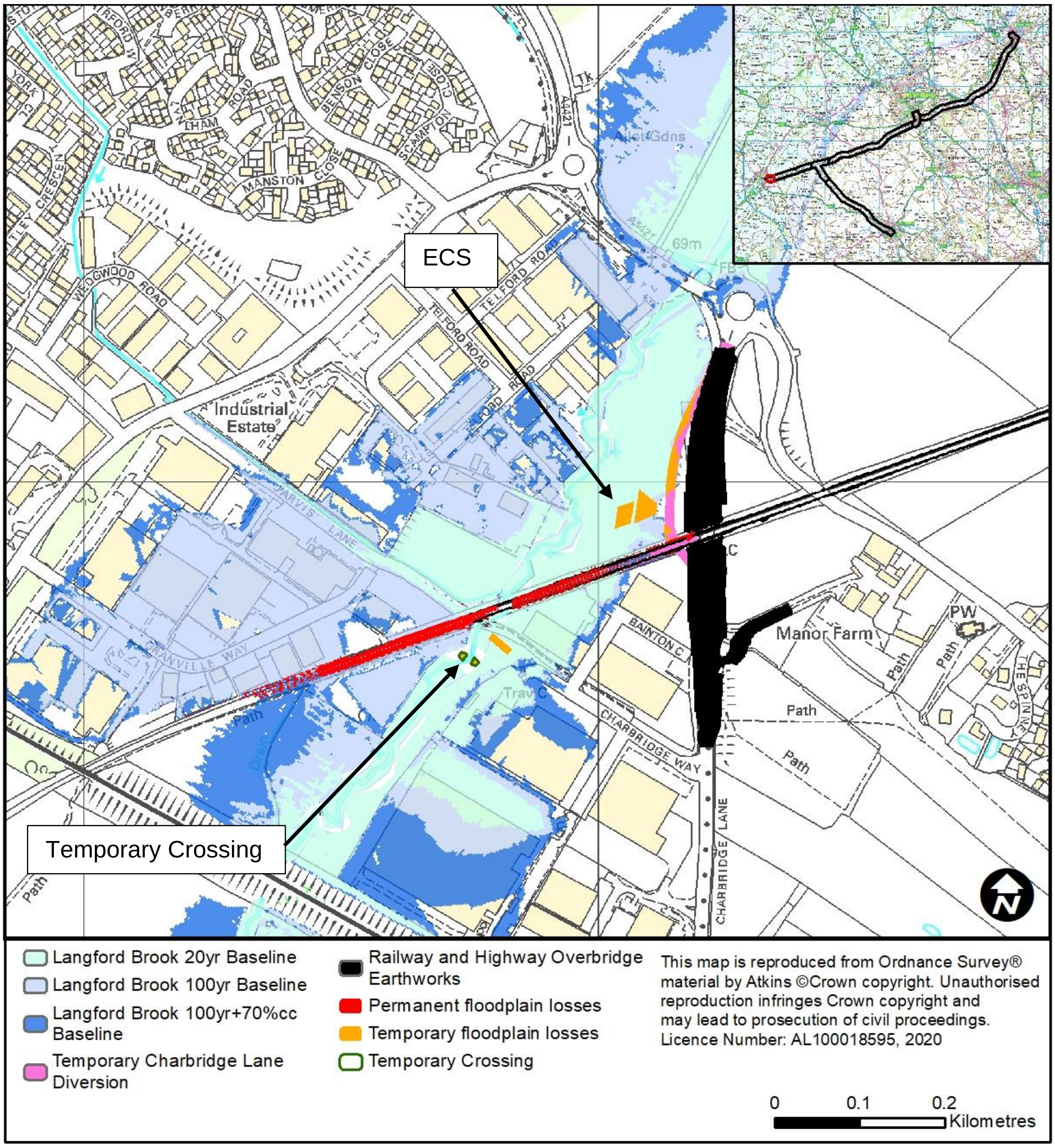


The temporary Charbridge Lane road diversion shown in Figure 3-5 will be in place for 12-14 months. This will pass through floodplain areas and therefore compensation will be required. There are two aspects to the proposed works that will impact the floodplain of Langford Brook, these are shown in the location plan below, namely:

- The temporary works required to divert the road during construction of the proposed new overbridge, temporary construction storage and haul road; and
- The permanent works comprising the proposed railway embankment works, the proposed overbridge, and the proposed backwater channel.

The WFD backwater lowers ground levels in the floodplain and therefore does not need to be accounted for in the assessment of floodplain losses.

Figure 3-5 Potential floodplain loss locations



Temporary and permanent works

There are a number of elements to both the permanent and temporary works which are outlined below, with the locations shown in Figure 3-5.

<u>Permanent Works</u>

- New highway overbridge (OXD/36AA Charbridge Lane);
- Improvements to the railway embankment earthworks (localised re-grades);
- Jarvis Lane footbridge; and

- A CFSA (2A0261/5.2/FH) proposed to mitigate the potential loss of floodplain due to planned permanent and temporary works.

Temporary Works

- Temporary construction storage and haul road (in place for 12-18 months);
- Temporary watercourse crossing (in place for 12 months); and
- Temporary highway diversion of Charbridge Lane (in place for between 12-14 months).

Construction sequence

The sequencing of the works and placement of materials have been designed to ensure that the combined volume of floodplain loss due to the permanent works and temporary works combined is less than that provided by the CFSA. This has been provided on a level for level basis and all works including the temporary case are compensated for up to a 1% annual chance event including 70% climate change allowance. This is therefore a precautionary approach. The CFSA will be in place prior to any works being undertaken.

There will be stockpiles at the eastern end of the CFSA which are not within the floodplain, these stockpiles fit within the temporary red line boundary.

The ECS, located north of the railway will be constructed following completion of the 2A1 permanent construction associated with the railway and overbridge works in this area. Temporary stockpiles associated with construction of permanent and temporary works, with a total storage volume of approximately 4500m³ will be stored in this area during construction. The footprint of stockpiles has been minimised (through increased bund height) and have been located in areas of least flood depth. This results in approximately 900m³ of floodplain loss.

South of the EWR2 line there will be a temporary watercourse crossing installed, this will be a clear span structure and has been included in the hydraulic model. The modelling results related to the temporary watercourse crossing required for the construction haul road will be supplied as an addendum to the consent application for the temporary watercourse crossing.

There will be a single stockpile south of the EWR2 line (total volume of approximately 900m³, of which approximately 100m³ is within the floodplain). The footprint of the stockpile has been minimised (through increased bund height) and have been located in areas of least flood depth. The Jarvis Lane footbridge falls partially within the floodplain, the volume of works within the floodplain is negligible at approximately 13m³.

Assessment of floodplain losses

A loss assessment was completed to show the volume of floodplain losses due to the works proposed. All raster data was resampled to a 0.2m cell size in order to produce an accurate loss estimate due to the small size of the loss area. The following data was used in this assessment:

- Existing ground model;
- Proposed ground model; and
- Flood level grids for all return periods.

The calculated losses are based on comparison of the baseline and With Scheme ground models compared against modelled flood levels. The location of floodplain losses is shown in Figure 3-5.

The 0.1% annual chance event has similar peak levels to the 1% annual chance event with an allowance for climate change and has been used for this analysis. For example, peak water levels at assessment point 2 for the 0.1% annual chance event and 1% annual chance event with an allowance for climate change are 69.75mAOD and 69.76mAOD respectively, and for assessment point 6 are 69.34mAOD and 69.37mAOD, respectively.

Table 3-2 Losses from permanent works

Annual Chance Event	Total Volume lost (m^3)	Flood level at gain site (mAOD)	Volume lost at Increment (m^3)
20%	25	69.17	25
5%	27	69.28	3
2%	63	69.45	36
1%	195	69.59	132
1% + 70% climate change	270	69.77	75

Table 3-3 Losses from permanent and temporary works combined

Flood Event	Total Volume lost (m^3)	Flood level at gain site (mAOD)	Volume lost at Increment (m^3)
20%	137	69.17	137
5%	460	69.28	323
2%	881	69.45	421
1%	1195	69.59	314
1% + 70% climate change	1450	69.77	255

The differences in peak flood levels shown above are too small to construct a viable compensation area at such fine scale, therefore the total losses have been condensed into 200mm bands deemed the minimum feasible for construction, as shown in the table below.

Table 3-4 CFSA Gains

Increment (at/up to level) based on loss level (mAOD)	Total Volume lost (temporary and permanent) at increment (m^3)	Volume Gained at increment (m^3)	Overprovision (temporary and permanent) (m^3)	Overprovision (permanent) (m^3)
69.17	137	440	303	415
69.37	323	595	272	592
69.57	421	617	196	581
69.77	569	635	66	428
Total (m^3)	**1450**	**2287**	**837**	**2017**

The CFSA provides a total storage volume of 2287m^3 giving an overprovision in storage for all level bands. This storage will remain in place when the temporary works are removed providing permanent additional floodplain storage for the catchment >2000m^3, and an overprovision during the temporary and permanent scenario of >800m^3.

4. With Scheme Modelling

As agreed with the Environment Agency on 4th February 2020, where a floodplain loss, caused by earthworks within the floodplain, is compensated for by a CFSA on a level for level basis then the With Scheme and CFSA modelling results do not need to be provided. The With Scheme scenario model will be provided as part of the modelling package supplied to the Environment Agency.

A CFSA will be provided to compensate for floodplain losses on a direct level for level basis (including significant over provision of floodplain storage). The CFSA has been designed on the eastern edge of the floodplain upstream of all floodplain losses, will extend the existing floodplain and is sized to include a significant overprovision.

The modelling results related to the temporary watercourse crossing required for the construction haul road will be supplied as an addendum to the consent application for the temporary watercourse crossing.

Blockage Assessment

The Project Wide FRA has indicated that a blockage assessment is required for culvert C180814 and that a quantitative assessment using the hydraulic model was considered necessary. Appendix F contains details about the results of this blockage assessment.

5. Conclusion

This CFSA Modelling Report has the following conclusions:

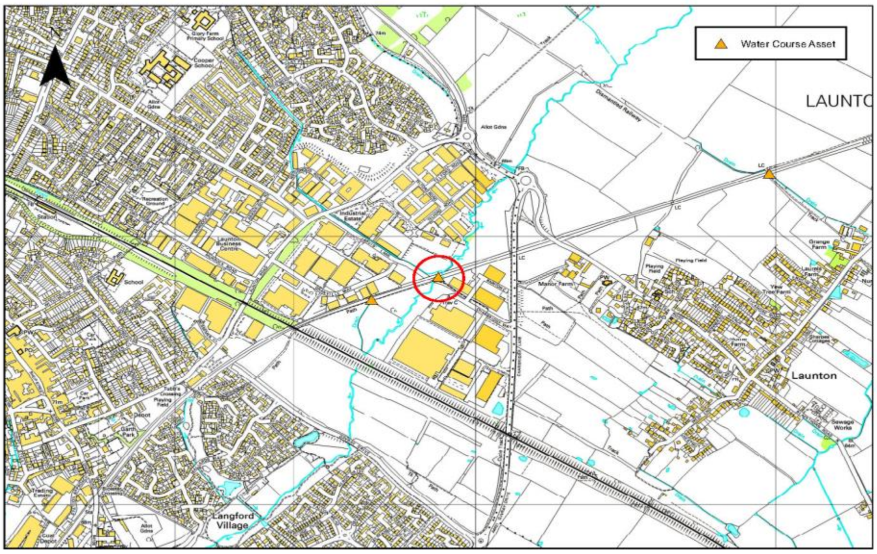
- This report is submitted to discharge Planning Condition 13 and is submitted in line with the Planning Condition 13 Phasing Strategy, and is located in development stage 2A1;
- The existing PBA hydrological and hydraulic model has been improved and used to assess flood risk to EWR2, the potential impacts of the Scheme and compensation options. The potential impacts of climate change were assessed by increasing flows by 70%;
- An assessment of the temporary floodplain losses arising from the temporary Charbridge Lane diversion works, temporary construction storage areas and temporary watercourse crossing, along with an assessment of the permanent floodplain volume losses arising from railway earthwork embankment improvements and highway overbridge works has been undertaken;
- The modelling results related to the temporary watercourse crossing required for the construction haul road will be supplied as an addendum to the consent application for the temporary watercourse crossing;
- The CFSA will be in place prior to any ground raising or storage works in the floodplain being undertaken. The hydrological and hydraulic model has been updated to include the combined (permanent and temporary) With Scheme proposal, and used to size the proposed CFSA. The proposed CFSA has been designed to compensate for the combined temporary and permanent works in line with CIRIA 624, and provides a total floodplain volume of 2287m^3; and
- The CFSA mitigates for both the temporary and permanent works. Once construction is complete and the temporary works removed from the floodplain there will be an additional floodplain storage volume >2000m^3 provided by the Scheme under the permanent scenario, and an overprovision during the temporary and permanent scenario of >800m^3. The Scheme is therefore providing a catchment betterment.

Appendix A. Project Wide FRA Site Summary

Summary Flood Risk Assessment

Asset Information

Site Location Map



Crossing reference/floodplain	2	
Route Section	2A	
Culvert ID	C180814	
NGR	459889, 222859	
EWR-ELR	OXD	
Lead Local Flood Authority	Oxfordshire County Council	
Environment Agency Region	Thames	
River Basin District	Thames	
Watercourse Type	Main River	
Water ES Chapter Watercourse Reference	2A 001	
Existing Culvert/Crossing Size	1450	(mm)
Existing Culvert/Crossing Length	12	(m)
Existing Culvert/Crossing Type	Brick Arch with Flat Bottom	

Proposed Works

Culvert Recommendation	CIPP liner for the entire length of the culvert. Existing headwalls to be repaired on both ends	
Track Level (at crossing point)	69.42	(mAOD)

Hydrological and Hydraulic Analysis

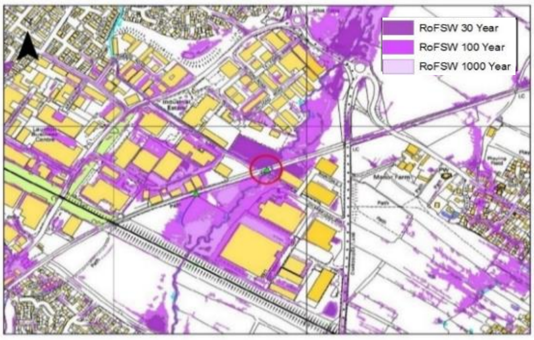
Climate Change allowance	70	(%)

	Flows (m³/s)	Embankment PWL (mAOD)	Freeboard to track (m)
100-year	6.96	69.08	0.34
100-year + 70% CC	6.98	69.01	0.42
1000-year	7.00	69.14	0.28

Performance Code	N/A	
Performance Code description	N/A	
Freeboard at 100-year event	<0.6	(m)

Floodplain Maps

RoFSW



Environment Agency Flood Zones

Description of groundwater flooding	Very low / Limited flood risk
Groundwater flood risk	This zone is deemed as having a negligible risk from groundwater flooding due to the nature of the geological deposits.

Proposed Mitigation	CFSA
Principal Flood Risk Source	Fluvial
Blockage Assessment Required	Yes

Sensitivity of Receptors

1) Floodplain or defence protecting more than 100 residential properties from flooding	No
2) Areas where highly vulnerable development is at risk of flooding - such as essential infrastructure, emergency services and basement dwellings.	No
	N/A
1) Floodplain or defence protecting between 1 and 100 residential properties or industrial premises from flooding.	Yes
2) Areas where development that is more vulnerable is at risk of flooding; hospitals, residential units, educational facilities and waste management sites.	Yes
	High
1) Floodplain or defence protecting 10 or fewer industrial properties from flooding.	No
2) Areas where less vulnerable development is at risk of flooding - such as retail, commercial and general industrial units, agricultural/forestry sites	No
	N/A
1) Floodplain with limited constraints and a low probability of flooding of residential and industrial properties.	No
2) Areas that are considered to be water-compatible; flood control infrastructure, docks/marinas, pumping stations and landscape/recreational areas	No
	N/A

Sensitivity of Receptor:	High

Magnitude of Impact

Construction

Excluding Mitigation	High Adverse

	Rating	Definition
Yes	High Adverse	· Increase in peak flood level (1% annual probability event) > 100mm. · Loss of functional floodplain flood storage areas.- Increases flood risk to property and/or infrastructure
No	Medium Adverse	· Increase in peak flood level (1% annual probability event) > 50mm. - increases flood risk to third party farm land/open space
No	Low Adverse	· Increase in peak flood level (1% annual probability event) > 10mm. - increases flood risk to Network Rail land
No	Very Low Adverse	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor increase in flood risk to Network Rail land
No	No Change	· No predicted adverse or beneficial impact to the receptor.
No	High Beneficial	· Reduction in peak flood level (1% annual probability event) > 100mm. -Decreases flood risk to property and/or infrastructure
No	Medium Beneficial	· Reduction in peak flood level (1% annual probability event) > 50mm. - Decreases flood risk to third party farm land/open space
No	Low Beneficial	· Reduction in peak flood level (1% annual probability event) > 10mm. -Decreases flood risk to Network Rail land
No	Very Low Beneficial	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor decrease in flood risk to Network Rail land

Including Mitigation	Very Low Adverse

	Rating	Definition
No	High Adverse	· Increase in peak flood level (1% annual probability event) > 100mm. · Loss of functional floodplain flood storage areas.- Increases flood risk to property and/or infrastructure
No	Medium Adverse	· Increase in peak flood level (1% annual probability event) > 50mm. - increases flood risk to third party farm land/open space
No	Low Adverse	· Increase in peak flood level (1% annual probability event) > 10mm. - increases flood risk to Network Rail land
Yes	Very Low Adverse	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor increase in flood risk to Network Rail land
No	No Change	· No predicted adverse or beneficial impact to the receptor.
No	High Beneficial	· Reduction in peak flood level (1% annual probability event) > 100mm. -Decreases flood risk to property and/or infrastructure
No	Medium Beneficial	· Reduction in peak flood level (1% annual probability event) > 50mm. - Decreases flood risk to third party farm land/open space
No	Low Beneficial	· Reduction in peak flood level (1% annual probability event) > 10mm. -Decreases flood risk to Network Rail land
No	Very Low Beneficial	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor decrease in flood risk to Network Rail land

Operation

Excluding Mitigation	High Adverse

	Rating	Definition
Yes	High Adverse	· Increase in peak flood level (1% annual probability event) > 100mm. · Loss of functional floodplain flood storage areas.- Increases flood risk to property and/or infrastructure
No	Medium Adverse	· Increase in peak flood level (1% annual probability event) > 50mm. - increases flood risk to third party farm land/open space
No	Low Adverse	· Increase in peak flood level (1% annual probability event) > 10mm. - increases flood risk to Network Rail land
No	Very Low Adverse	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor increase in flood risk to Network Rail land
No	No Change	· No predicted adverse or beneficial impact to the receptor.
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No	Medium Beneficial	· Reduction in peak flood level (1% annual probability event) > 50mm. - Decreases flood risk to third party farm land/open space

No	Low Beneficial	· Reduction in peak flood level (1% annual probability event) > 10mm. -Decreases flood risk to Network Rail land
No	Very Low Beneficial	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor decrease in flood risk to Network Rail land

Including Mitigation	Very Low Adverse

	Rating	Definition
No	High Adverse	· Increase in peak flood level (1% annual probability event) > 100mm. · Loss of functional floodplain flood storage areas.- Increases flood risk to property and/or infrastructure
No	Medium Adverse	· Increase in peak flood level (1% annual probability event) > 50mm. - increases flood risk to third party farm land/open space
No	Low Adverse	· Increase in peak flood level (1% annual probability event) > 10mm. - increases flood risk to Network Rail land
Yes	Very Low Adverse	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor increase in flood risk to Network Rail land
No	No Change	· No predicted adverse or beneficial impact to the receptor.
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No	Very Low Beneficial	· Negligible change in peak flood level (1% annual probability event) < 10mm. - very minor decrease in flood risk to Network Rail land

Significance of Effect

Construction

Sensitivity of Receptor	High
Magnitude (beneficial/adverse) (excluding mitigation)	High Adverse
Potential Significance of Effect (excluding mitigation)	Major
Magnitude (beneficial/adverse) (including mitigation)	Very Low Adverse
Residual Significance of Effect (including mitigation)	Minor
Include in Environmental Statement Main Body	YES

Operation

Sensitivity of Receptor	High
Magnitude (beneficial/adverse) (excluding mitigation)	High Adverse
Potential Significance of Effect (excluding mitigation)	Major
Magnitude (beneficial/adverse) (including mitigation)	Very Low Adverse
Residual Significance of Effect (including mitigation)	Minor
Include in Environmental Statement Main Body	YES

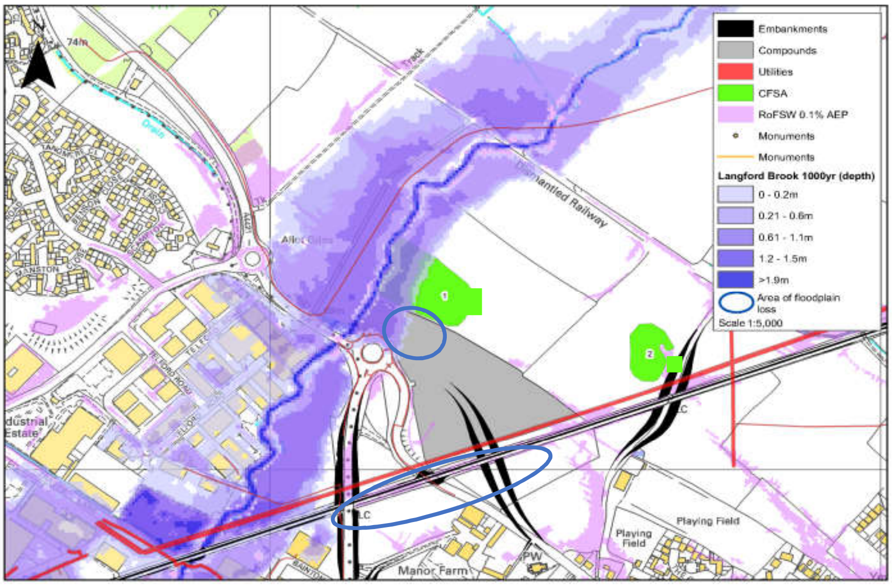
Summary

This assessment has been based on existing Environment Agency RoFSW flooding and Flood Zones 2 and 3, and the Langford Brook Hydraulic Model (ISIS/TUFLOW). In this location, the flood risk is fluvial and surface water related, with the track shown to lie in Flood Zone 2 and 3 and be at risk from surface water by the 30-year event upwards. Assets within the floodplain are the Network Rail land, more than 10 adjoining industrial/commercial properties, and several urban roads. There is limited groundwater flood risk in this area. Works comprise - embankment works limited to a restricted area at the crossing point; a level crossing to be closed and replaced with stepped footbridge with provision for cycle channel; new footpath proposed to create a formalised footpath crossing; a new overbridge to replace existing highway (A4421) crossing, 250m away from this location. Existing culvert to be rehabilitated using CIPP liner for the entire length of the culvert. The overbridge embankment falls outside the edge of the floodplain. The Langford Brook 1D/2D model indicates that the culvert is under capacity (the head water elevation is higher than the culvert soffit level), and that the track is flooded from the 100-year event upwards. The 100-year, 100-year plus 70% climate change, and 1000-year return periods have been modelled. A CFSA is proposed to mitigate the impact of the works. As a CFSA has been proposed to provide storage for the flood water displaced by the widening of the railway embankment footprint and for the works to the culvert, the change in flood risk is considered to be minimal. The works compound A1 Bicester lies in the Flood Zone 2 and 3 and in an area shown to be at risk of surface water flooding for the 30-year event; there is a potential for an increase in runoff from increased hardstanding areas as a result of the compound; a surface water management plan will be developed to manage this. The compound should be organised so that infrastructure and storage within the floodplain is minimised. Further information is required on the compound layout to help inform the level of mitigation required since this compensation would be for temporary works. The increase in impermeable area from the bridge will be mitigated for. A haul road is proposed in this location, which crosses an area at risk of fluvial (Flood Zone 2 and 3) and surface water flooding. The proposed haul road route does not cross any watercourse, and therefore will not require a new culvert crossing. The haul road route will be at existing ground level and will not therefore result in a loss of floodplain storage.

Appendix B. CFSA Summary Report

CFSA Summary

Site Location Map



CFSA Number	2A0061 / 5.2 / FH
Route Section	2A
NGR	460286, 223307
EWR-ELR	OXD
Lead Local Flood Authority	Oxfordshire County Council
Environment Agency Region	Thames
Flood Risk Source	Fluvial and Surface water
Works requiring CFSA	Compound, railway and overbridge embankment works

Floodplain Loss Information

	Losses at embankment		Losses at compound	
Area of proposed works in the 1000-year event floodplain	532	m^2	4960	m^2
Indicative floodplain volume loss (1000-year)	296	m^3	1810	m^3

Existing ground levels at the loss (LiDAR)		Minimum Elevation (m AOD)	Maximum Elevation (m AOD)	Difference in level (m)
	Embankment	66.9	69.2	2.3
	Compound	68.5	69.8	1.3

Proposed CFSA

Estimated area required based on floodplain loss	1928	m^2
Proposed CFSA area	7273	m^2
Minimum Indicative CFSA Volume (0.1m excavation depth)	364	m^3
Maximum Indicative CFSA Volume (excavation to maximum available depth)	7273	m^3

	Minimum Elevation (m AOD)	Maximum Elevation (m AOD)	Difference in level (m)
Existing levels at proposed CFSA (LiDAR)	68.0	70.2	2.2

Summary

This assessment has been based on the existing Environment Agency RoFSW maps and the Langford Brook hydraulic modelling results. The proposed CFSA has been designed to provide storage for losses arising from embankment widening and works compound A1 Bicester. The CFSA is located approximately 10m north of the main floodplain loss (the compound); this location avoids committed development and high voltage exclusion zones. The CFSA will drain back into the Langford Brook.

Loss of floodplain Storage calculation

1) At the loss of floodplain – in order to derive the level-area relationship for the land lost as floodplain the following steps are undertaken:
   a) Calculate the area (m^2) under the footprint of the Project that is flooded during a 1 in 1000-year event
      (using modelled data/RoFSW 1 in 1000-year outline / Environment Agency Flood Zone 2).
   b) An automated depth/area Arc GIS tool was used to calculate the level area relationship, to derive an estimate of floodplain volume lost.

a) Floodpain loss (m²)	532.00
Peak Water Level (mAOD)	69.20
b) Floodplain Volume Loss (m³)	296.19

Water Level Source: Langford Brook hydraulic model

Level Area relationship embankment

WetArea (m²)	Elevation (mAOD)	DryArea (m²)	Volume (m³)
0.00	66.00	672.00	0.00
0.00	66.10	672.00	0.00
0.00	66.20	672.00	0.00
0.00	66.30	672.00	0.00
0.00	66.40	672.00	0.00
0.00	66.50	672.00	0.00
0.00	66.60	672.00	0.00
0.00	66.70	672.00	0.00
0.00	66.80	672.00	0.00
12.00	66.90	660.00	0.45
28.00	67.00	644.00	2.32
44.00	67.10	628.00	5.57
56.00	67.20	616.00	10.59
60.00	67.30	612.00	16.36
68.00	67.40	604.00	22.76
76.00	67.50	596.00	29.92
80.00	67.60	592.00	37.63
80.00	67.70	592.00	45.63
96.00	67.80	576.00	54.38
116.00	67.90	556.00	65.16
144.00	68.00	528.00	78.38
160.00	68.10	512.00	93.47
172.00	68.20	500.00	110.09
176.00	68.30	496.00	127.30
176.00	68.40	496.00	144.90
180.00	68.50	492.00	162.75
188.00	68.60	484.00	181.13
192.00	68.70	480.00	200.19
192.00	68.80	480.00	219.39
192.00	68.90	480.00	238.59
192.00	69.00	480.00	257.79
192.00	69.10	480.00	276.99
192.00	**69.20**	**480.00**	**296.19**
212.00	69.30	460.00	316.43
224.00	69.40	448.00	337.91
312.00	69.50	360.00	363.43
408.00	69.60	264.00	399.24
508.00	69.70	164.00	7273.00
516.00	69.80	156.00	496.90
532.00	69.90	140.00	548.77
624.00	70.00	48.00	606.40
664.00	70.10	8.00	671.35
672.00	70.20	0.00	738.43
672.00	70.30	0.00	805.63
672.00	70.40	0.00	872.83
672.00	70.50	0.00	940.03
672.00	70.60	0.00	1007.23
672.00	70.70	0.00	1074.43
672.00	70.80	0.00	1141.63
672.00	70.90	0.00	1208.83
672.00	71.00	0.00	1276.03

a) Floodpain loss (m²)	4960.00
Peak Water Level (mAOD)	69.80
b) Floodplain Volume Loss (m³)	1809.82

Water Level Source: Langford Brook hydraulic model

Level Area relationship compund

WetArea (m²)	Elevation (mAOD)	DryArea (m²)	Volume (m³)
0.00	68.00	4960.00	0.00
0.00	68.10	4960.00	0.00
0.00	68.20	4960.00	0.00
0.00	68.30	4960.00	0.00
0.00	68.40	4960.00	0.00
20.00	68.50	4940.00	0.78
20.00	68.60	4940.00	2.78
52.00	68.70	4908.00	6.61
112.00	68.80	4848.00	13.84
204.00	68.90	4756.00	29.62
292.00	69.00	4668.00	54.50
424.00	69.10	4536.00	89.77
1080.00	69.20	3880.00	157.13
1840.00	69.30	3120.00	308.23
2320.00	69.40	2640.00	515.45
2844.00	69.50	2116.00	774.91
3304.00	69.60	1656.00	1084.43
3684.00	69.70	1276.00	1436.62
3768.00	**69.80**	**1192.00**	**1809.82**
3800.00	69.90	1160.00	2188.71
3812.00	70.00	1148.00	2569.42
3824.00	70.10	1136.00	2951.12
3844.00	70.20	1116.00	3334.51
3856.00	70.30	1104.00	3719.60
3864.00	70.40	1096.00	4105.72
3868.00	70.50	1092.00	4492.45
3868.00	70.60	1092.00	4879.24
3868.00	70.70	1092.00	5266.04
3868.00	70.80	1092.00	5652.86
3936.00	70.90	1024.00	6042.43
4084.00	71.00	876.00	6442.30
4284.00	71.10	676.00	6864.55
4328.00	71.20	632.00	7295.77
4344.00	71.30	616.00	7729.27
4372.00	71.40	588.00	8165.52
4484.00	71.50	476.00	8607.12
4652.00	71.60	308.00	9063.33
4928.00	71.70	32.00	9540.25
4960.00	71.80	0.00	10035.86
4960.00	71.90	0.00	10531.85
4960.00	72.00	0.00	11027.84

At proposed CFSA (see Figure for further detail)

2) At the CFSA location - identify a location outside the existing floodplain where this level-area can be provided in accordance with the following criteria:

a) The location was positioned outside the 1 in 1000-year flood outlines but would include for excavation to the bank level of an existing watercourse, drain or flood outline extent, in order to remain hydraulically connected and allow for level for level replacement where possible. Constraints such as existing infrastructure were avoided and the number of landowners minimised.

b) The level of the 1 in 1000-year flood outline (whether modelled flood extent, Flood Zones or RoFSW) was taken at the CFSA location. This, and the local bank level, provides the depth of flood water over which storage could be provided, by extending the flooded area outside the current flood extents.

c) The required storage will have a zero depth of water at its most inland point (away from the watercourse) with the maximum depth adjacent to the existing 1 in 1000-year flood extent. Hence a wedge shape with maximum depth at the existing extent of the flood outline and zero depth at the inland end requires double the plan area to provide the same volume.

d) The width of the CFSA along the watercourse was measured. The required CFSA area (calculated above) was divided by this length which gave the width of the CFSA area inland. The difference between the existing ground level and the 1 in 1000-year water level is the depth of excavation required at this point. The level at the back of the CFSA, where water depth will be zero, would be the existing 1 in 1000-year flood level.

Bank level at CFSA location (m AOD)	1000yr WL at CFSA (m AOD)	Max storage depth 1000yr WL- Bank level (m)	Average area required (Volume/max storage depth) (m²)	Required storage area (Average area *2) (m²)	Proposed CFSA Area (m²)	Length along CFSA x (m)
68.00	70.18	2.18	135.61 828.61	1928.43	7273.43	107.04

Back slope for excavation calculation

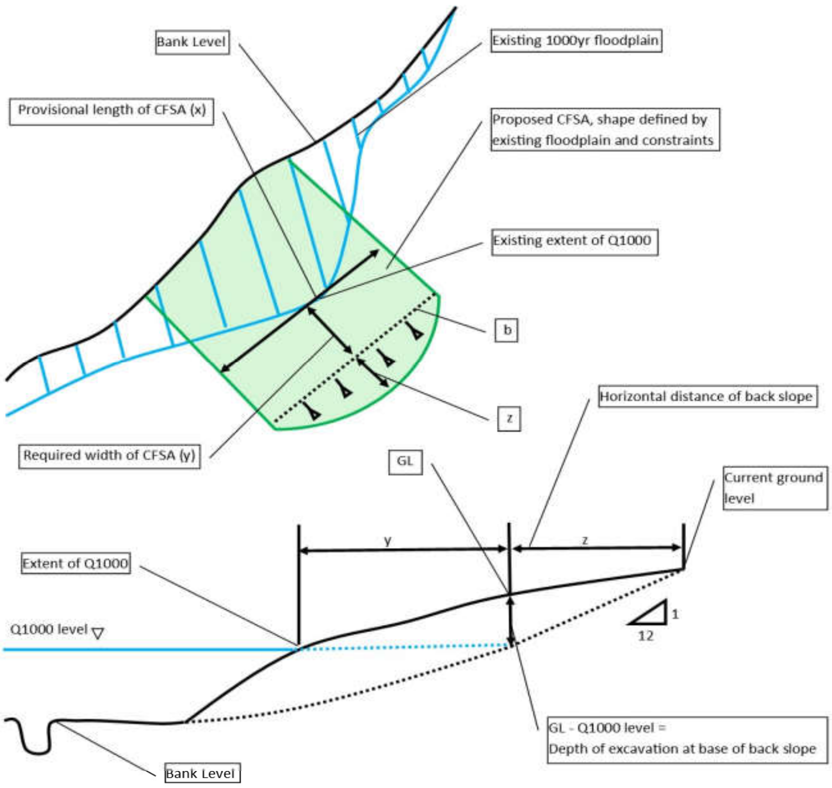
3) Make adequate provision for earthworks to tie the excavated area to existing ground levels in the proposed CFSA:

a) The depth (m) of excavation is derived based on the difference between the ground level (m AOD), taken from LiDAR, at the rear (landward) side of the CFSA before back slope, and the 1 in 1000-year flood level (m AOD).

b) Assume a 1 in 12 cut slope to obtain a horizontal length (m) of excavation.

c) Apply that distance (m) as an offset to the rear (landward) boundary of the defined CFSA to describe the full area of land to be allowed for the CFSA.

Offset y (m)	Ground level GL (mAOD)	Depth of excavation (GL-1000yr WL) (m)	Backslope length (m)	Does this fit inside the drawn area?
18.02	70.72	0.53	6.40	Y



1) Bank level, assumed to be threshold at which flooding occurs.
2) 1000yr level taken from Flood Zone 2 or RoFSW 1000yr map at CFSA location.
3) x = distance of CFSA adjacent to the watercourse.
4) y = the flood free area of CFSA divided by distance x (CFSA Area /x = y).
5) Take ground level (GL) midway along line b.
6) Depth of excavation at base of back slope of storage area is GL midway along line b - Q1000 (GL - Q1000 elevation = depth of excavation).
7) z = Depth of excavation at the base of back slope x12

*All levels based on LiDAR.

Appendix C. Environment Agency correspondence

From: Gordon, Clark P <clark.gordon@environment-agency.gov.uk>
Sent: 23 May 2019 16:18
To: Cox, Andrew (Water Management Consultancy); Moeran, Jack
Subject: RE: EWR2 - Langford Brook Flows

Dear Andrew,

Thank you for your query in relation to the modelling of flows on the Langford Brook.

We agree with the proposed approach, including the use of the PBA Langford Brook (2009) flows. Please note that we will expect you to make an assessment of the most current and relevant climate change scenarios.

If you have any further queries, please do not hesitate to contact me.

**Our comments are based on our available records and the information as submitted to us. Please note that any views expressed in this response by the Environment Agency, are a response to a pre-application enquiry only and do not represent our final views in relation to any future planning application made in relation to this site. We reserve the right to change our position in relation to any such application. You should seek your own expert advice in relation to technical matters relevant to any planning application before submission.*

Kind regards,

Clark Gordon
Strategic Planning Specialist, Strategic Planning & Engagement (Thames)
Environment Agency | Red Kite House, Howbery Park, Wallingford, Oxon, OX10 8BD

clark.gordon@environment-agency.gov.uk
External: 0203 025 8998 | Mobile: 07557 846789

Creating a better place for people and wildlife

Speak to us early about environmental issues and opportunities - We can provide a free pre-application advice note or for more detailed advice / meetings / reviews we can provide a project manager to coordinate specialist advice / meetings which costs £100 per hour (plus VAT). For more information email us at planning_THM@environment-agency.gov.uk

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From: Cox, Andrew (Water Management Consultancy) [mailto:Andrew.Cox@atkinsglobal.com]
Sent: 17 May 2019 14:18
To: Moeran, Jack <jack.moeran@environment-agency.gov.uk>
Cc: Gordon, Clark P <clark.gordon@environment-agency.gov.uk>
Subject: EWR2 - Langford Brook Flows

Dear Jack,

I hope you're well? We would be grateful for your response on the below.

The purpose of this email is to propose a method for estimating flows in the Langford Brook for the Network Rail, East West Rail Phase 2 (EWR2) Bedford to Bicester Improvements project, and to seek Environment Agency approval of the proposed approach.

A Flood Risk Mapping Study of Langford Village and Bicester was undertaken by Peter Brett Associates (PBA) in December 2009 (Project Ref 15945/006) on behalf of the Environment Agency, Thames Region (West Area). This study included the Langford Brook. The hydrology was reviewed by Atkins and it was recommended that the flows be compared using new data and methods (including FEH13, ReFH2, WINFAP4 and an updated AMAX series).

We have recalculated flows for the Langford Brook using the most up to date methods and data available (WINFAP4 using peak flow data to October 2018, ReFH2 and ReFH). It should be noted that we have not used the rating to calculate flows because the gauge is an Environment Agency Flood Warning gauge; a rating was developed by PBA for the 2009 event, but all check gaugings were carried out at low flows and these did not fit the rating very well. A comparison of the QMED and 100-year flow estimates at the Langford Brook flood warning gauge, just downstream of the railway crossing is shown below.

	Peak flow (m^3/s)			
Return period (years)	**PBA Study (2009)**	**EWR2 (2019) - FEH Statistical**	**EWR2 (2019) - ReFH2**	**EWR2 (2019) - ReFH**
QMED	2.25	1.2	1.3	1.7
100	7.02	3.5	3.6	4.5

We are proposing for EWR2 that we use the existing PBA (2009) flows because these are the most conservative. We are seeking Environment Agency approval on the proposed approach described above, before proceeding further with the flood modelling and Compensatory Flood Storage Area design.

If you would like to discuss please let me know.

Kind regards,

Andrew Cox *C.WEM, C.Sci, C.Env, MCIWEM, C.Geog*
Principal Consultant
UK & Europe
Engineering, Design and Project Management

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Company

creating a better place

Environment Agency

Andrew Cox
Atkins
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Bristol
BS32 4RZ

Our ref: WA/2019/126657/02-L01
Your ref: 133735-2A-EWR-OXD-XX-RP-DC-000012

Date: 30 September 2019

Dear Andrew,

East West Rail Phase 2 - review of Langford Brook Modelling and CFSA Briefing Note

Thank you for sending us the Langford Brook Compensatory Flood Storage Area (CFSA) Briefing Note (reference: 133735-2A-EWR-OXD-XX-RP-DC-000012; dated: 16 September 2019; revision: B01), which we received from you on 16 September.

As we caveated in our response for the Launton Brook CFSA Briefing Note (our reference: WA/2019/126905/01-L01; dated: 21 August 2019), we welcome that you have updated the existing approved modelling to better understand flood risk. We note this includes updated topographic survey data and the inclusion of new culvert features. We will need to review and sign off the updates to this modelling before we are in a position to approve the final details of the CFSA. Therefore, please submit all model files for us to review. Until we have signed off these updates we will not be able to sign off the model outputs as fit for purpose. Therefore, any further comments below come with the caveat that the updated modelling has not yet been signed off.

Following our review, and subject to the submission of acceptable updated modelling:

We agree that if the modelling confirms that the temporary compound is outside of the 1 in 100 plus 70% then it does not need to be compensated for.

We agree that the temporary road diversion (Charbridge) will only need to provide compensation up to the 1 in 100 year level. This is because of the temporary nature of the works.

We are pleased that compensation is being provided for all permanent works up to the 1 in 100 plus 70% event. We expect this to be on a level for level basis.

Reference is made to temporary culvert(s) under the road. These must be designed to accommodate existing flood flows. If this is not possible then an assessment of the impacts of altering flood flow routes must be carried out to ensure there is no increase in flood risk.

We welcome the opportunity to further discuss your query around providing compensation for temporary and permanent losses whilst minimising impacts. However, this may be an issue that we first discuss at the forthcoming regulators workshop, which

Cont/d..

you're aware I'm in the process of setting up. However, if there is a site-specific query that you have in the meantime, we would be happy to discuss this further.

If you have any queries about this response, please do not hesitate to contact me.

Yours sincerely,

Clark Gordon
Strategic Planning Specialist

Direct dial 0203 025 8998
E-mail clark.gordon@environment-agency.gov.uk

cc Adrian Rose – Atkins
Wayne Barker – Oxfordshire County Council

Cox, Andrew (Water Management Consultancy)

From: Lebrun, Antoine <Antoine.Lebrun@environment-agency.gov.uk>
Sent: 08 July 2020 16:01
To: Cox, Andrew (Water Management Consultancy); Gordon, Clark; Moeran, Jack
Cc: Powell, Michael; Wilcock, John
Subject: RE: EWR2 - Langford Brook flood modelling meeting 7/7/20 summary

Good afternoon,

Thank you for the summary.
Just two little comments:

- *"AL has requested that we provide the minimum timestep and the number of repeated timesteps from the HPC run"*
  You can just send me the results of the run you have done with TUFLOW HPC there should be some outputs that will help me answer this myself.
- Could you also please send all the survey that you have about this river? Xsections and really interested in structures too.

Apologise for forgetting to mention that during the meeting.

Kind regards,

Antoine Lebrun
Evidence & Risk, Quality & Assurance Advisor
Environment Agency

External phone number: 02077 120 666 or 07342 077 962
Internal phone number: 20666
E-mail: antoine.lebrun@environment-agency.gov.uk
Environment Agency, Richard Fairclough House Knutsford Road, Warrington, WA4 1HT

From: Cox, Andrew (Water Management Consultancy) [mailto:Andrew.Cox@atkinsglobal.com]
Sent: 08 July 2020 15:49
To: Lebrun, Antoine <Antoine.Lebrun@environment-agency.gov.uk>; Gordon, Clark <clark.gordon@environment-agency.gov.uk>; Moeran, Jack <jack.moeran@environment-agency.gov.uk>
Cc: Powell, Michael <Michael.Powell@atkinsglobal.com>; Wilcock, John <John.Wilcock@atkinsglobal.com>
Subject: EWR2 - Langford Brook flood modelling meeting 7/7/20 summary

Good Afternoon,

Thank you again for your time on the call yesterday. Below is a summary of the meeting:

- JW and MP provided a brief update of the additional modelling undertaken since the Environment Agency model review to address the concerns of the initial review and increase confidence in the model outputs. Environment Agency were happy that the model is now improved.

- Schematics of the previous and updated model were shown to demonstrate the extents of the trimmed model. The reasons for trimming the model and justifications for the locations of the downstream boundary and 2d boundary were explained.
- Peak flood extents of the previous and updated model were shown. It was explained that the differences in the model extents are due to the increased resolution of the model (2m rather than 10m) and newer LiDAR, which represent the rail embankments and roads more accurately, with peak water levels consistent with the previous model. This changes the volume of overtopping flow between flood cells. Environment Agency commented that the model now appears to be much better so are comfortable with the changes presented, with further review to be undertaken.
- Sensitivity hydrographs were presented to demonstrate that the parameters which have been changed to stabilise the model do not significantly impact on the model results. AL has requested that we provide the minimum timestep and the number of repeated timesteps from the HPC run.
- Flood warning and potential changes to the flood warning system were mentioned by AL, whilst noting that it is not something we need to address in this work but perhaps something the Environment Agency need to look at internally. JW explained the floodplain storage is compensatory and on a level for level basis so would be replacing lost volume from the proposed earthworks, and the compensatory floodplain volumes represent a small proportion of the total floodplain volume. It should not therefore impact the current flood warning provision.
- A summary of the hydrology was presented. The Environment Agency were happy with the approach used.
- The Environment Agency confirmed cross section spacing was acceptable and that any model health check issues are ok as long as they do not impact on results.
- A comparison of peak water levels at the downstream boundary of the previous and updated model was presented, along with the results from the sensitivity tests. Environment Agency confirmed they were happy with the approach for the downstream boundary, and the results, based on what was presented.
- Atkins are to upload the model for the Environment Agency on Monday 13th July. Upload must include sensitivity tests to allow reviewer to compare results. Check files are not required.
- A follow up meeting has been scheduled for Thursday 16th July at 14.30 to discuss, if required, any outstanding issues with the updated model, with a view to aid swift sign off of the model.

Any questions please let me know.

Kind regards,

Andrew Cox *C.WEM, C.Sci, C.Env, MCIWEM, C.Geog*
Principal Consultant
UK & Europe
Engineering, Design and Project Management

+44 1454 662289 +44 78123 18631

The Hub, 500 Park Avenue, Aztec West, Bristol, BS32 4RZ

Company

Cox, Andrew (Water Management Consultancy)

From:	Lebrun, Antoine <Antoine.Lebrun@environment-agency.gov.uk>
Sent:	21 July 2020 11:48
To:	Cox, Andrew (Water Management Consultancy); Gordon, Clark
Cc:	Wilcock, John; Powell, Michael; Moeran, Jack
Subject:	RE: EWR2 - Langford Brook Modelling meeting notes 16/7/20
Attachments:	EWR_LangfordBrook_Hydraulic_2020.xlsm

Good morning,

Please find attached the latest version of the review spreadsheet.

Clark & Jack – I'll be away all August going on a mission for the French Red Cross against Ebola in DRC, therefore if you need help from E&R please use the QFM formal route.

Kind regards,

Antoine Lebrun
Evidence & Risk, Quality & Assurance Advisor
Environment Agency

External phone number: 02077 120 666 or 07342 077 962
Internal phone number: 20666
E-mail: antoine.lebrun@environment-agency.gov.uk
Environment Agency, Richard Fairclough House Knutsford Road, Warrington, WA4 1HT

From: Cox, Andrew (Water Management Consultancy) [mailto:Andrew.Cox@atkinsglobal.com]
Sent: 21 July 2020 10:08
To: Lebrun, Antoine <Antoine.Lebrun@environment-agency.gov.uk>; Gordon, Clark <clark.gordon@environment-agency.gov.uk>
Cc: Wilcock, John <John.Wilcock@atkinsglobal.com>; Powell, Michael <Michael.Powell@atkinsglobal.com>; Moeran, Jack <jack.moeran@environment-agency.gov.uk>
Subject: EWR2 - Langford Brook Modelling meeting notes 16/7/20

Good Morning,

Thank you again for your time on Thursday 16th July to discuss the updated Langford Brook flood modelling.

Antoine - would you be able to send through the updated review spreadsheet so we can ensure we include the relevant details/figures in the updated CFSA modelling report?

Below is a brief summary of the key points from the meeting:

- Antoine Lebrun is happy with the improved Langford Brook model and his review comments have been addressed. Atkins now need to update the CFSA modelling report to include this information.
- Atkins need to provide the figures/comparisons, responses to comments and sensitivity tests in the updated CFSA modelling report (with some in the main body of the report and some in the Appendix). This is to

include information on the updated modelling results at the Langford Brook flood warning gauge to flag this as something the Environment Agency may need to review in terms of their flood warning system.

- Clark Gordon noted that due to the timeframes the Environment Agency may need to formally object to the planning condition for this site until the CFSA modelling report is re-submitted.

Any questions please let me know.

Kind regards,

Andrew Cox *C.WEM, C.Sci, C.Env, MCIWEM, C.Geog*
Principal Consultant
UK & Europe
Engineering, Design and Project Management

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Company

Appendix D. Topographic Survey

DO NOT SCALE

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

MAINTENANCE/CLEANING

DECOMMISSIONING/DEMOLITION

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

Rev.	Date	Description	By	Chk'd	App'd

Drawing Status: FOR INFORMATION

Suitability: S0

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Fax: +44 (0)1245 345010
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Client: EWR Alliance

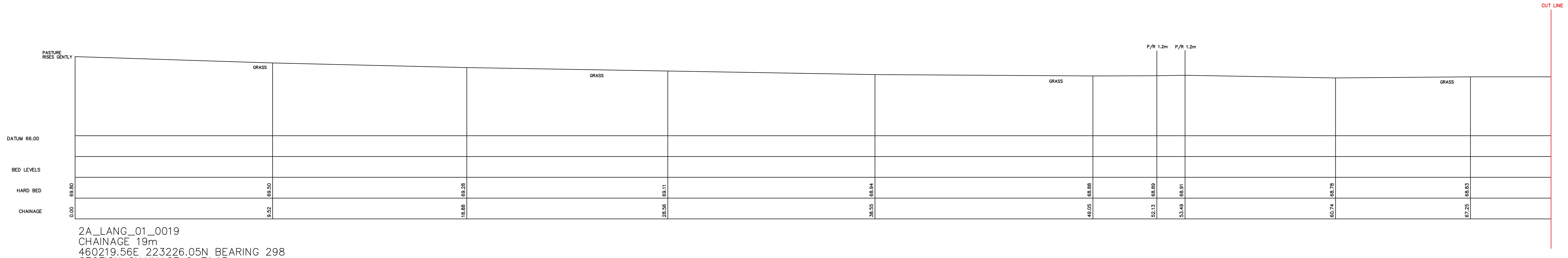
Project Title: EAST WEST RAIL SECTION 2A LANGFORD BROOK WATERCOURSE CROSS SECTIONS

Drawing Title: LANGFORD BROOK WATERCOURSE SECTION KEYPLAN

Scale	Designed	Drawn	Checked	Reviewed
1:1250	--	B.MAAS	G.COLDWELL	N.MENDHAM
Original Size	Date	Date	Date	Date
A1	--/--/--	26/07/19	26/07/19	26/07/19

Drawing Number	Revision
13375_RW-EWR-XX-2A_LANG-M2-G-010001	P01

DO NOT SCALE



2A_LANG_01_0019
CHAINAGE 19m
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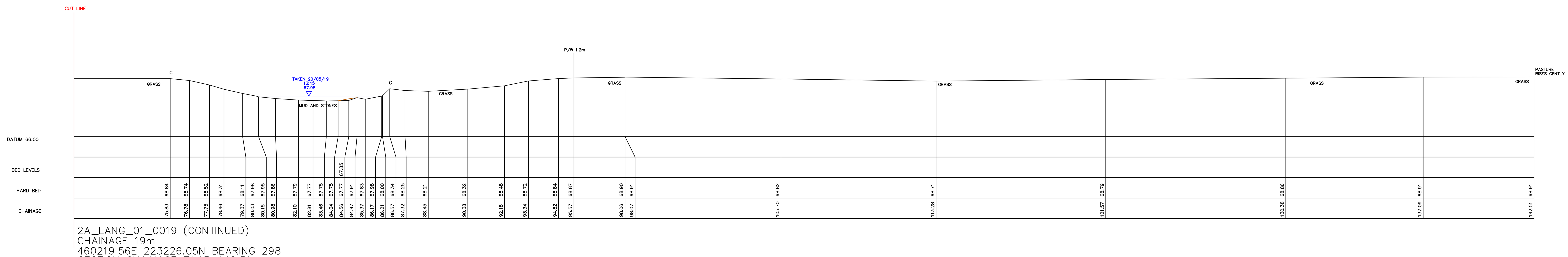
SECTION CHAINAGE 0–71.13m



2A_LANG_01_0019 (CONTINUED)
CHAINAGE 19m
460219.56E 223226.05N BEARING 298
SECTION CHAINAGE 71.13–142.51m

All cross sections viewed looking downstream

SURVEY LEGEND

C	Bank Crest
C/B	Fence – Close Boarded
C/I	Fence – Corrugated Iron
C/L	Fence – Chain Link
C/P	Fence – Chestnut
FP	Fence – Parapet Fence
FPG	Fence – Pedestrian Rail
FSF	Fence – Safety Fence
I/R	Fence – Iron Railings
I/W	Fence – Wattle/Interwoven
L/L	Fence – Larch Lap
P/BW	Fence – Post & Barbed Wire
P/R	Fence – Post & Rail
P/S	Fence – Pale & Space
P/W	Fence – Post & Wire
S/R	Fence – Steel Railings
TSR	Fence – Tubular Steel Railings

Refer to drawing 133735_RW-EWR-XX-2B_WATE-M2-G-010001 for section location information

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

MAINTENANCE/CLEANING

DECOMMISSIONING/DEMOLITION

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

Rev.	Date	Description	By	Chk'd	App'd

Drawing Status: FOR INFORMATION
Suitability: S0

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Client: EWR Alliance

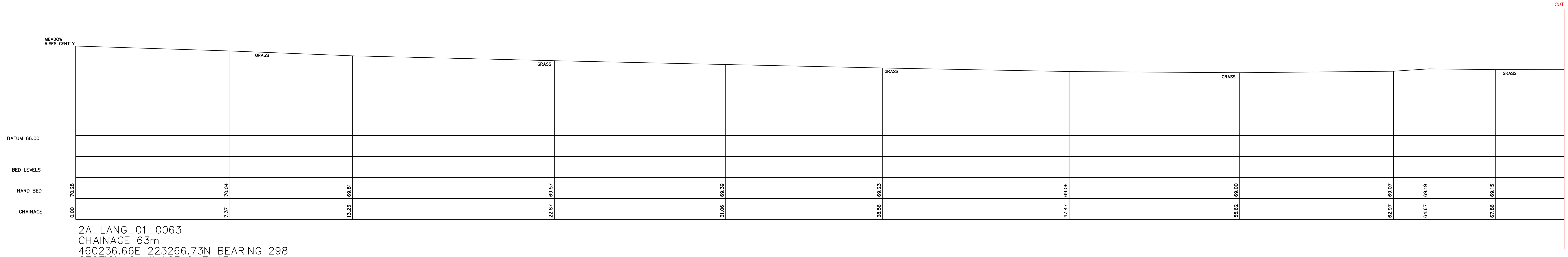
Project Title: EAST WEST RAIL SECTION 2A
LANGFORD BROOK
WATERCOURSE CROSS SECTIONS

Drawing Title: CHANNEL NO.1
CROSS SECTIONS
CHAINAGE 19m

Scale	Designed	Drawn	Checked	Reviewed
1:100	--	B.MAAS	G.COLDWELL	N.MENDHAM
Original Size: A1	Date: --/--/--	Date: 26/07/19	Date: 26/07/19	Date: 26/07/19

Drawing Number: 13375_RW-EWR-XX-2A_LANG-M2-G-010002
Revision: P01

DO NOT SCALE



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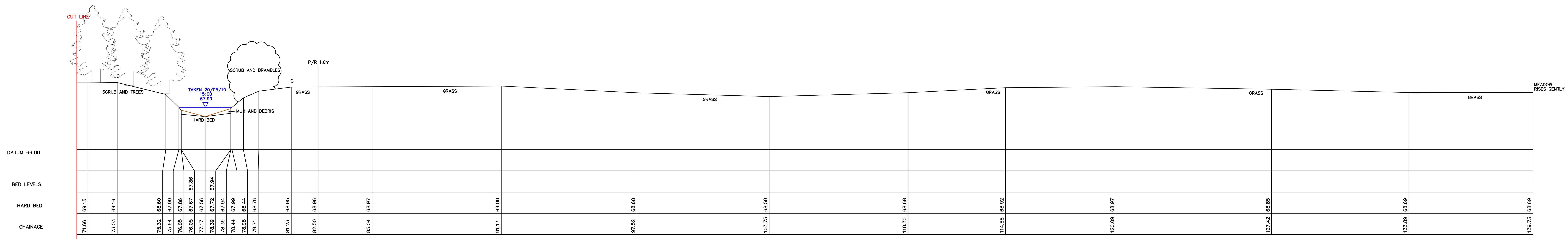
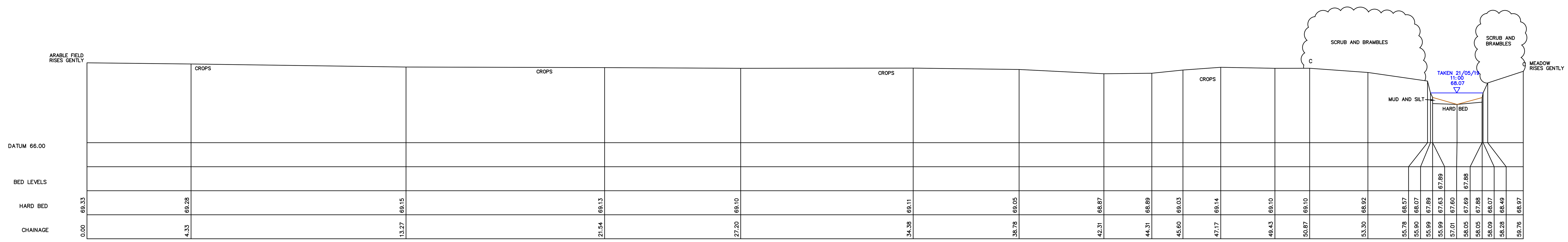
SECTION CHAINAGE 0–71.13m



2A_LANG_01_0063
CHAINAGE 63m
460236.66E 223266.73N BEARING 298
SECTION CHAINAGE 71.13–139.73m



2A_LANG_01_0160
CHAINAGE 160m
460244.25E 223380.06N BEARING 282
SECTION CHAINAGE 0–59.76m

All cross sections viewed looking downstream

SURVEY LEGEND

C	Bank Crest
C/B	Fence – Close Boarded
C/I	Fence – Corrugated Iron
C/L	Fence – Chain Link
C/P	Fence – Chestnut
FP	Fence – Parapet Fence
FPG	Fence – Pedestrian Rail
FSF	Fence – Safety Fence
I/R	Fence – Iron Railings
I/W	Fence – Wattle/Interwoven
L/L	Fence – Larch Lap
P/BW	Fence – Post & Barbed Wire
P/R	Fence – Post & Rail
P/S	Fence – Pale & Space
P/W	Fence – Post & Wire
S/R	Fence – Steel Railings
TSR	Fence – Tubular Steel Railings

Refer to drawing 133735_RW-EWR-XX-2B_WATE-M2-G-010001 for section location information

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

MAINTENANCE/CLEANING

DECOMMISSIONING/DEMOLITION

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

Rev.	Date	Description	By	Chk'd	App'd

Drawing Status: FOR INFORMATION
Suitability: S0

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Fax: +44 (0)1245 345010
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Client: EWR Alliance

Project Title: EAST WEST RAIL SECTION 2A LANGFORD BROOK WATERCOURSE CROSS SECTIONS

Drawing Title: CHANNEL NO.1 CROSS SECTIONS CHAINAGE 63-160m

Scale	Designed	Drawn	Checked	Reviewed
1:100	--	B.MAAS	G.COLDWELL	N.MENDHAM
Original Size	Date	Date	Date	Date
A1	--/--/--	26/07/19	26/07/19	26/07/19

Drawing Number	Revision
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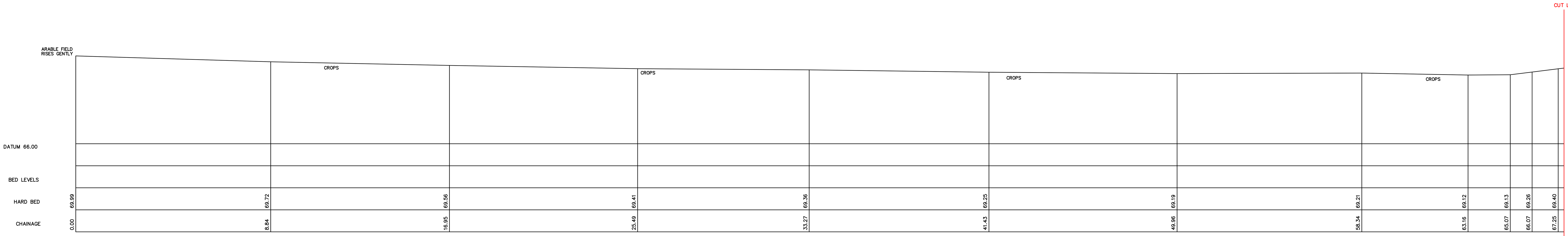
DO NOT SCALE



2A_LANG_01_0243
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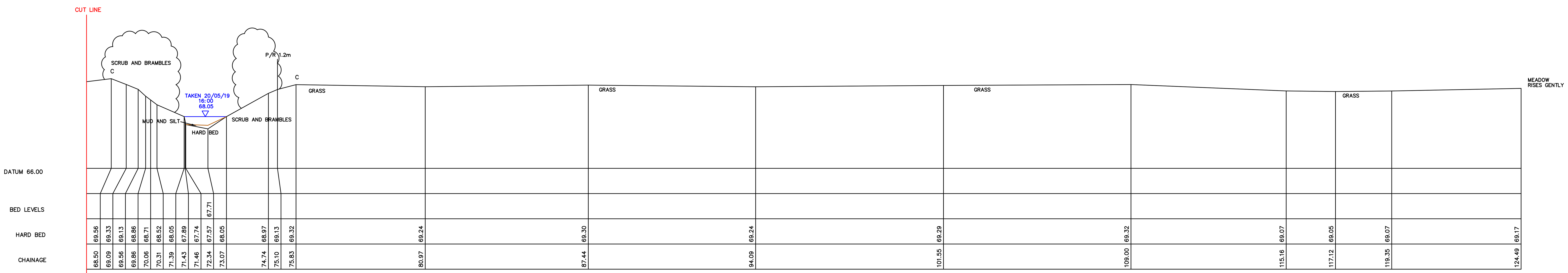
460293.91E 223415.22N BEARING 305
SECTION CHAINAGE 0–67.51m



2A_LANG_01_0243
CHAINAGE 243m
460293.91E 223415.22N BEARING 305
SECTION CHAINAGE 67.51–124.49m

All cross sections viewed looking downstream

SURVEY LEGEND

C	Bank Crest
C/B	Fence – Close Boarded
C/I	Fence – Corrugated Iron
C/L	Fence – Chain Link
C/P	Fence – Chestnut
FP	Fence – Parapet Fence
FPG	Fence – Pedestrian Rail
FSF	Fence – Safety Fence
I/R	Fence – Iron Railings
I/W	Fence – Wattle/Interwoven
L/L	Fence – Larch Lap
P/BW	Fence – Post & Barbed Wire
P/R	Fence – Post & Rail
P/S	Fence – Pale & Space
P/W	Fence – Post & Wire
S/R	Fence – Steel Railings
TSR	Fence – Tubular Steel Railings

Refer to drawing 133735_RW-EWR-XX-2B_WATE-M2-G-010001 for section location information

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

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DECOMMISSIONING/DEMOLITION

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

Rev.	Date	Description	By	Chk'd	App'd

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Suitability: S0

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Client: EWR Alliance

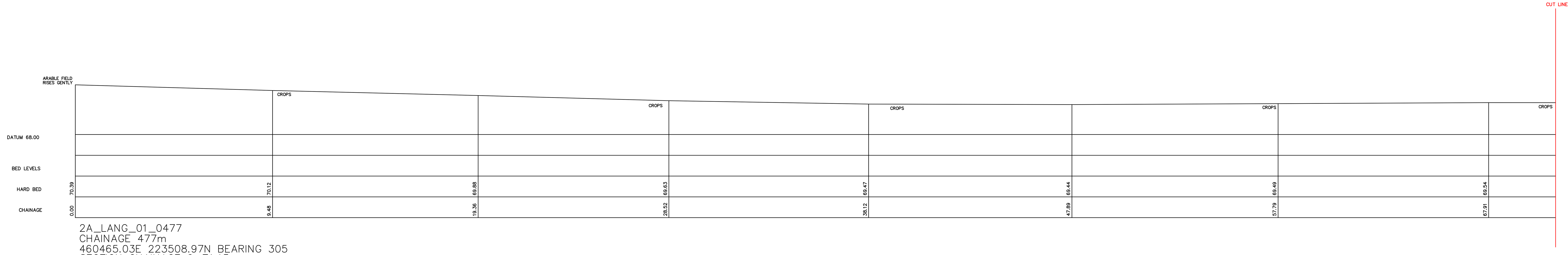
Project Title: EAST WEST RAIL SECTION 2A LANGFORD BROOK WATERCOURSE CROSS SECTIONS

Drawing Title: CHANNEL NO.1 CROSS SECTIONS CHAINAGE 243m

Scale	Designed	Drawn	Checked	Reviewed
1:100	--	B.MAAS	G.COLDWELL	N.MENDHAM
Original Size: A1	Date: --/--/--	Date: 26/07/19	Date: 26/07/19	Date: 26/07/19

Drawing Number: 13375_RW-EWR-XX-2A_LANG-M2-G-010004
Revision: P01

DO NOT SCALE



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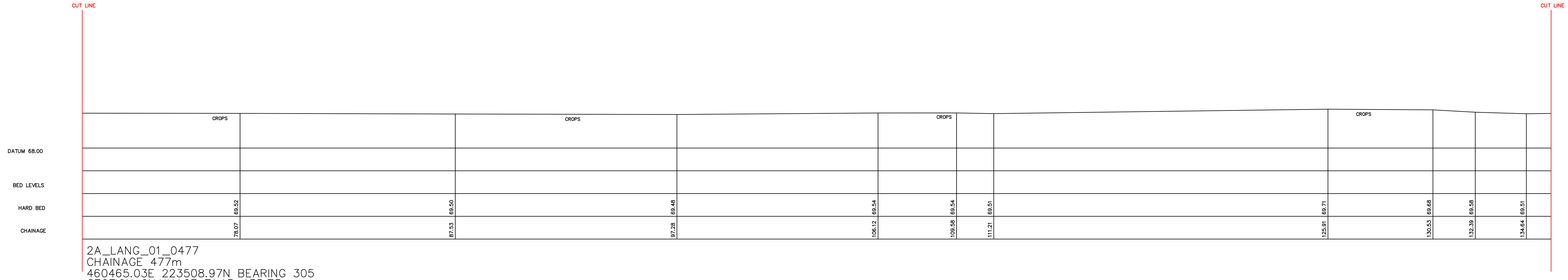
460465.03E 223508.97N BEARING 305
SECTION CHAINAGE 0–71.13m



2A_LANG_01_0477
CHAINAGE 477m
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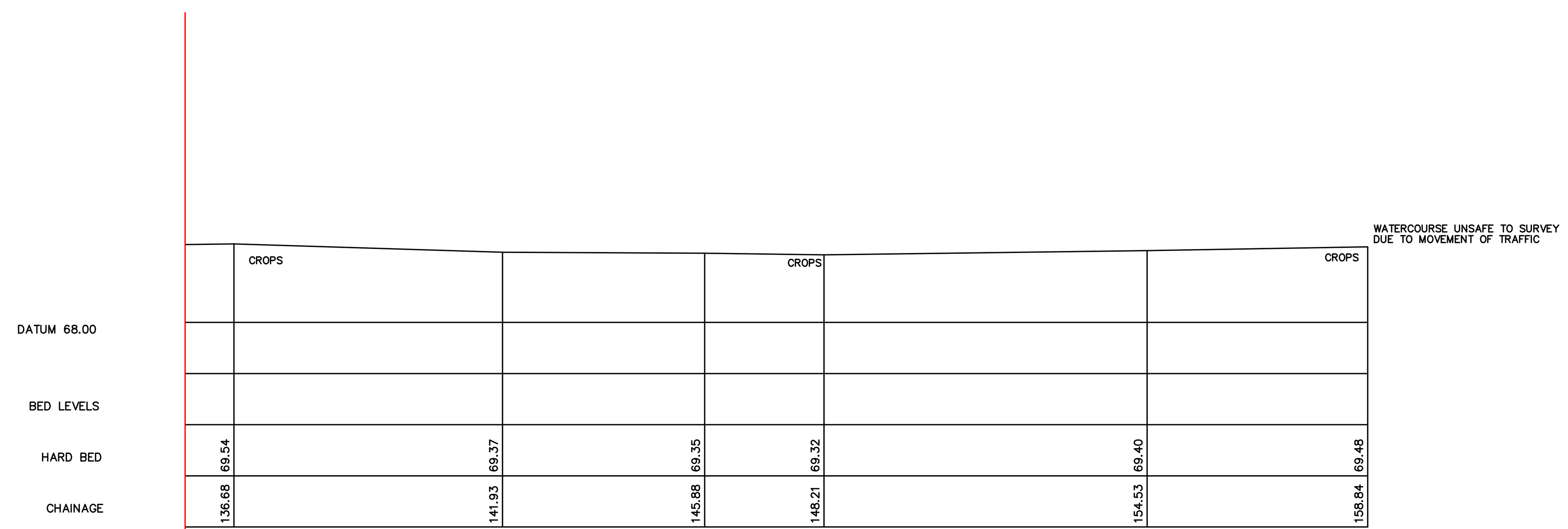
SECTION CHAINAGE 71.13–135.73m



2A_LANG_01_0477
CHAINAGE 477m
460465.03E 223508.97N BEARING 305
SECTION CHAINAGE 135.73–158.84m

All cross sections viewed looking downstream

SURVEY LEGEND

C	Bank Crest
C/B	Fence – Close Boarded
C/I	Fence – Corrugated Iron
C/L	Fence – Chain Link
C/P	Fence – Chestnut
FP	Fence – Parapet Fence
FPG	Fence – Pedestrian Rail
FSF	Fence – Safety Fence
I/R	Fence – Iron Railings
I/W	Fence – Wattle/Interwoven
L/L	Fence – Larch Lap
P/BW	Fence – Post & Barbed Wire
P/R	Fence – Post & Rail
P/S	Fence – Pale & Space
P/W	Fence – Post & Wire
S/R	Fence – Steel Railings
TSR	Fence – Tubular Steel Railings

Refer to drawing 133735_RW-EWR-XX-2B_WATE-M2-G-010001 for section location information

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

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DECOMMISSIONING/DEMOLITION

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Rev.	Date	Description	By	Chk'd	App'd

Drawing Status: FOR INFORMATION
Suitability: S0

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Client: EWR Alliance

Project Title: EAST WEST RAIL SECTION 2A LANGFORD BROOK WATERCOURSE CROSS SECTIONS

Drawing Title: CHANNEL NO.1 CROSS SECTIONS CHAINAGE 477m

Scale	Designed	Drawn	Checked	Reviewed
1:100	--	B.MAAS	G.COLDWELL	N.MENDHAM
Original Size	Date	Date	Date	Date
A1	--/--/--	26/07/19	26/07/19	26/07/19

Drawing Number: 13375_RW-EWR-XX-2A_LANG-M2-G-010005
Revision: P01

Appendix E. FEH Calculation Record

Flood estimation calculation record

INTRODUCTION

This document is a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at multiple locations.

CONTENTS

APPROVAL

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:	[redacted]	Charlotte Sugden Senior Hydrologist BSc (Hons), MSc, MCIWEM, C.WEM, C.Sci	2
Calculations checked by:	[redacted]	Tracey Ashworth Senior Hydrologist BSc (Hons), MSc, MCIWEM, C.WEM, C.Sci	3
Calculations approved by:	[redacted]	Andrew Cox Principal Consultant C.WEM, C.Sci, C.Env, MCIWEM, C.Geog	2

Environment Agency competence levels are covered in Section 2.1 of the flood estimation guidelines:

- Level 1 – Hydrologist with minimum approved experience in flood estimation
- Level 2 – Senior Hydrologist
- Level 3 – Senior Hydrologist with extensive experience of flood estimation

ABBREVIATIONS

AMAX	Annual Maximum
AREA	Catchment area (km^2)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

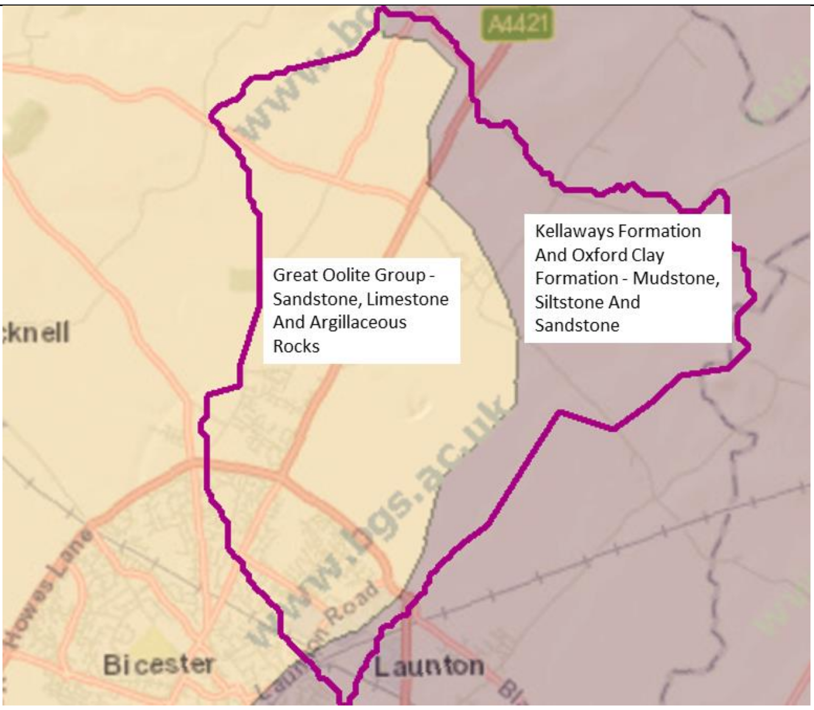
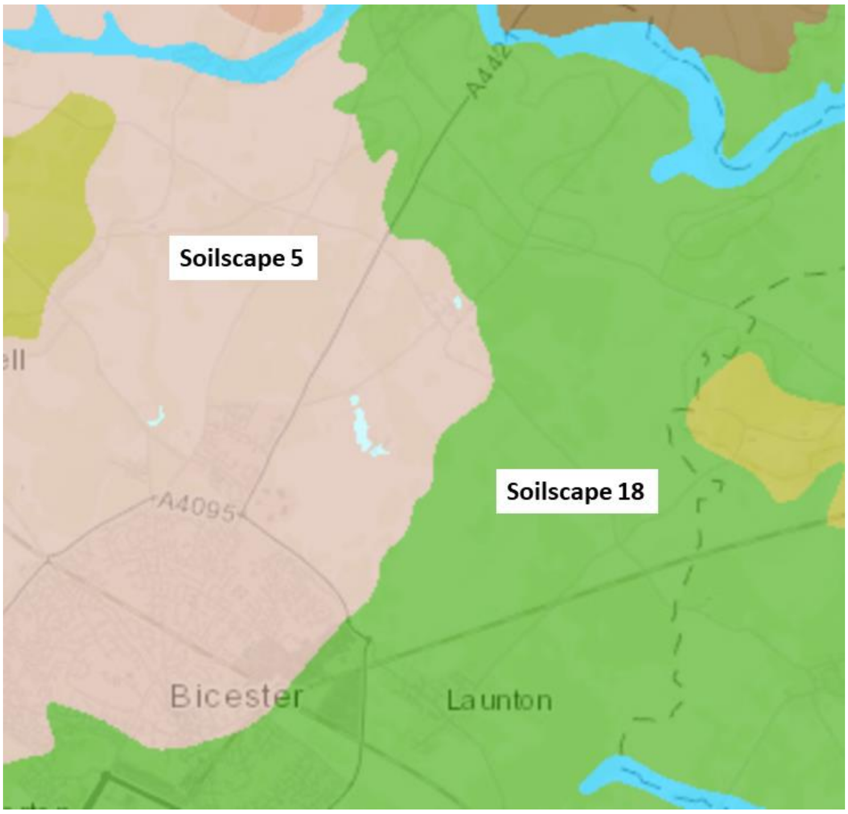
1.1 Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: • Purpose of study • Approx. no. of flood estimates required • Peak flows or hydrographs? • Range of return periods and locations • Approx. time available	The hydrology is being prepared as part of the Network Rail, East West Rail Phase 2 (EWR2), Bedford to Bicester improvements project. The project comprises track re-doubling (in some locations) and line speed improvement works from the east of Bicester to Bedford (Route Sections 2A – 2D) and south from Calvert Junction to Aylesbury (HS2 Interface Area and Route Section 2E). To accommodate these improvement works, earthworks and drainage solutions, such as Compensatory Flood Storage Areas (CFSAs) are being proposed. This hydrology is for Langford Brook, which flows through Bicester. There is a temporary compound and a CFSA proposed along the left bank of the brook. There are also two existing railway crossings of the watercourse. A hydraulic model will be used to assess the potential impacts of the EWR2 works, and design flood flows are needed as model inputs. The hydraulic model for Langford Brook is an existing Environment Agency approved model that will be truncated to just downstream of the A41. The inflows used in this existing model will be reviewed as part of this assessment. The locations for flow estimates are shown in the map in the Annex. The approximate location of the CFSA, temporary compound, railway crossings and Langford Flood Warning gauge are also shown.

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	The catchment of interest is Langford Brook, to the point just downstream of the A41. A map showing the sub-catchments is in the Annex. The catchment has been split up into sub-catchments for the purposes of the hydraulic modelling. The location of the sub-catchments will allow a comparison with the flows calculated as part of an Environment Agency Flood Risk Mapping Study undertaken in 2009[1]. The total catchment area to the flood warning gauge, which is just downstream of the railway crossings is 17.8 km^2. Langford Brook initially flows in a south easterly direction from its source near Fringford. From Stratton Audley the watercourse flows south west to Langford village. The geology underlying the catchment is mainly Sandstone, Limestone and Argillaceous rocks in the west and Mudstone, Siltstone and Sandstone in the east. There are also some superficial deposits of alluvium along the watercourses. This is shown below (the catchment boundary to the flood warning gauge is shown in purple).

[1] Bicester Flood Risk Mapping Study (TH718) – Final Modelling Report, PBA 2009 written on behalf of the Environment Agency.

	 The soils are mainly Soilscape 5 (Freely draining lime-rich loamy soils) to the north and west and Soilscapes 18 (Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils) to the east, as shown below: 

1.3 Source of flood peak data

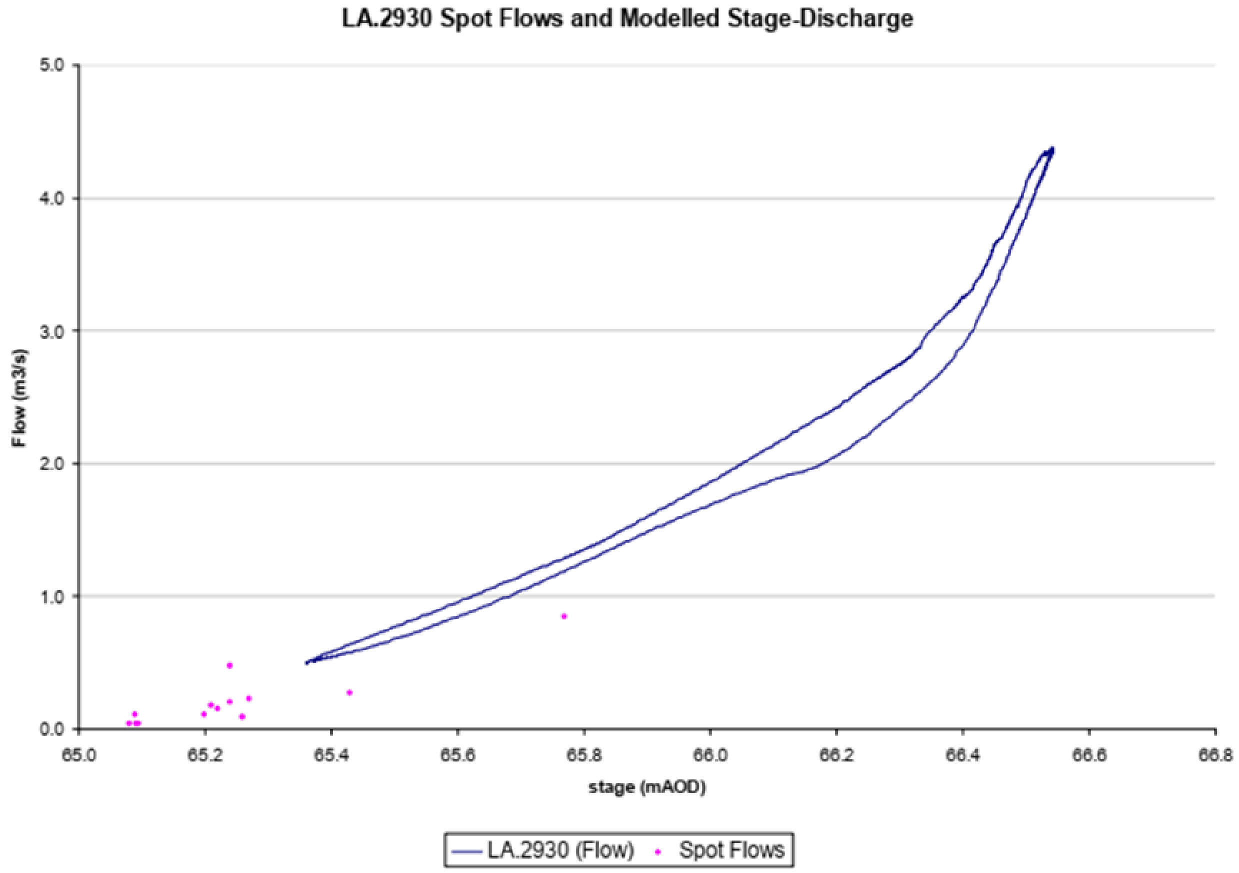
Was the HiFlows UK dataset used? If so, which version? If not, why not? Record any changes made	Yes – Version 7, October 2018

1.4 Gauging stations (flow or level)

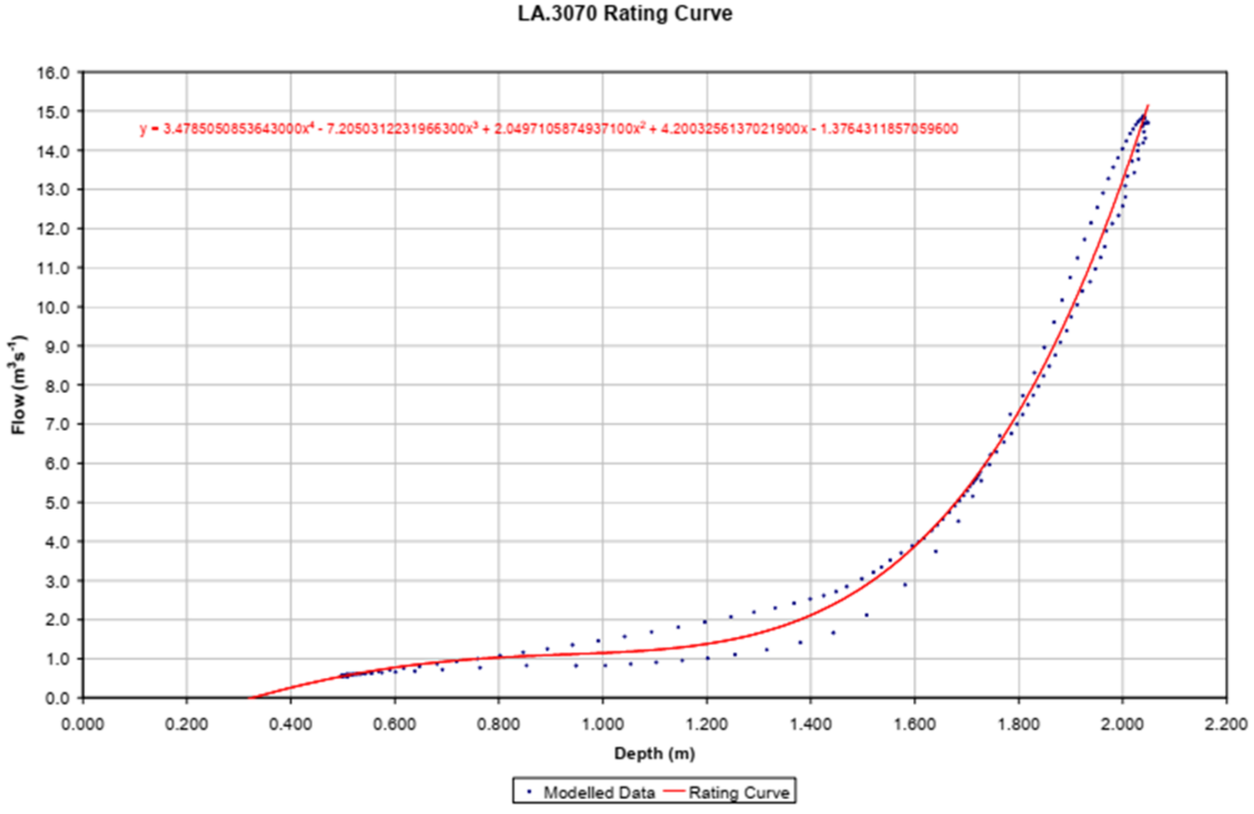
Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasonic / level…)	Start and end of flow record
Langford Brook	Langford Village (Station ID – 1484TH)	N/A	N/A	459577 222230	17.8	Level	2004-present

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	**Other comments on station and flow data quality** – e.g. information from HiFlows-UK, trends in flood peaks, outliers.
Langford Village	N/A	No	N/A	N/A	N/A	The gauge is an Environment Agency flood warning gauge and records levels only. A rating was created for the Environment Agency's Flood Risk Mapping Study; however, the rating equations and check gaugings have not been provided for use in this study. Therefore, a review of the rating has not been undertaken. Data is missing from 08/09 to 14/09/2010, 19/10 to 02/11/2011, 26/03/ to 27/03/2012, 10/03 to 24/04//2015 and a small period of missing timesteps between 07/02 and 08/02/2016.
Give link/reference to any further data quality checks carried out			Plots of the rating are available in the flood risk mapping report and are reproduced below. The rating was developed from spot gaugings undertaken at low flows and an ISIS hydraulic model. The spot gaugings indicate that the rating may overestimate flows.			



The rating developed using the ISIS hydraulic model is below (in this plot the water levels are in metres rather than mAOD).



1.6 Other data available and how it has been obtained

<table>
<tr><th>Type of data</th><th>Data relevant to this study?</th><th>Data available?</th><th>Source of data and licence reference if from EA</th><th>Date obtain -ed</th><th>Details</th></tr>
<tr><td>Check flow gaugings (if planned to review ratings)</td><td>Yes</td><td>No</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Historic flood data – give link to historic review if carried out.</td><td colspan="5">There are no Environment Agency records of historic flood events within 2 km of the Langford Village gauge.

The Flood Risk Mapping Study report states:
“The Chronology of British Hydrological Events (http://www.dundee.ac.uk/geography/cbhe/) holds no information on historic flood events for the Bicester area. PBA also contacted the Bicester local history society but were not successful in finding any other recorded historic events.”

The Flood Risk Mapping Study report also mentions 2 recorded out of bank flood events in Bicester, although neither of them has reported any flooding to properties.
1. 10th January 2007, when Langford Brook overtopped. The recorded level at Langford Village gauge was 1.731 m.
2. 20th July 2007, when there was extensive out of bank flooding from Langford brook and Pingle Stream. The recorded level at Langford Village gauge was 1.804 m.

The following flood event has also been reported around Bicester since 2009:
1. There was flooding on the River Bure in December 2013[2] – a tributary which joins the Langford Brook just downstream of our area of interest; however, no flood warning was issued on Langford Brook.</td></tr>
<tr><td>Flow data for events</td><td>Yes</td><td>Yes (although level not flow data)</td><td>Environment Agency
THM114407_MM
Open Government License</td><td>18/02/ 2019</td><td>15-minute interval level data from 2004 to 2018</td></tr>
<tr><td>Rainfall data for events</td><td>No</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Potential evaporation data</td><td>No</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Results from previous studies</td><td>Yes</td><td>Yes</td><td></td><td></td><td>Bicester Flood Risk Mapping Study (TH718) – Final Modelling Report, PBA 2009 written on behalf of the Environment Agency.</td></tr>
<tr><td>Other data or information (e.g. groundwater, tides)</td><td>Yes</td><td>Groundwater levels for the past year were obtained from gaugemap.co.uk for Fringford Ps Obh.</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

[2] http://modgov.cherwell.gov.uk/documents/s22704/Appendix%201.pdf?txtonly=1

1.7 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments). If not, describe other methods to be used.	Yes
Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	The main site of interest for this study is the CFSA which is proposed to compensate for earthwork losses. Flooding is likely to be as a result of a high flood peaks from the upper catchment and also possible backing up at the culvert location. Some of the catchment is underlain by limestone.
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – avoid standard ReFH if URBEXT1990>0.125; consider FEH statistical or other alternatives; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing • extensive floodplain storage – consider choice of method carefully	The catchment at the flood warning gauging station (just downstream of the railway crossing) has a catchment area of 17.8 km^2, an SPRHOST of 23%, some attenuation (FARL 0.961) and is moderately urban (URBEXT2000 0.08). The small catchments which flow into Langford Brook from the west are urbanised and permeable with SPR values less than 10%.
Initial choice of method(s) and reasons Will the catchment be split into subcatchments? If so, how?	FEH methods have limitations on permeable and urban catchments. In the statistical method, QMED calculated by catchment descriptors is uncertain on permeable catchments and local data should be used in preference where available. For heavily urbanised catchments where URBEXT is <0.5, if there is little difference between the topographic and sewer catchments, or the study is interested in extreme events above the sewer capacity, the statistical method with urban adjustment can be used. It is not known whether the topographic and sewer catchments differ in the Langford Brook catchment. However, the study is interested mainly in events above the average sewer capacity. Guidance on the use of ReFH2 has not yet been received from the Environment Agency; however, ReFH is not recommended for application to catchments with BFIHOST > 0.75. ReFH is also not recommended for catchments with URBEXT1990>0.125. The initial choice of method is to:

	• Calculate peak flows using the statistical method at the flood warning gauge for direct comparison with the hydrology in the Flood Risk Mapping Study. • Calculate inflows to the model using the ReFH and ReFH2 methods. The flows will be run through the hydraulic model and compared with the statistical method peak flow estimates at the flood warning gauge. If appropriate, the inflows will be scaled to match these peak flows. The catchment was split into sub-catchments based on the location of previous study's sub-catchments (in order to make a direct comparison) and also the location of the temporary compound, the CFSA, the flood warning gauge and the railway watercourse crossings.
Software to be used (with version numbers)	FEH online WINFAP-FEH v4[3] and Flood Modeller v4.3 / ReFH2

[3] WINFAP-FEH v4 © Wallingford HydroSolutions Limited and NERC (CEH) 2016.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

2.1 Summary of subject sites

Site code	Watercourse	Easting	Northing	AREA on FEH (km^2)	Revised AREA if altered
Lang_US	Langford Brook upstream hydraulic model inflow	461200	224700	9.46	10.30
Lateral_1	Langford Brook lateral inflow from Lang_US to CFSA	460350	223800	2.86	5.73
Lateral_2	Langford Brook lateral inflow from CFSA to downstream boundary	459800	222850	0.68	5.34
Lang_FW	Langford Brook (Flood Warning Gauge)	459600	222200	17.15	17.82
Reasons for choosing above locations	1. Lang_US is the upstream model inflow. 2. Lateral1 and Lateral2 are the lateral or intermediate catchment inflows. Catchment descriptors for these were taken from the drainage path within each lateral area. 3. Lang_FW is the flood warning gauge and flows were estimated here using the FEH statistical method only for comparison with the previous study flows and as a site to check the flows in the hydraulic model.				

2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROP-WET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPR-HOST	URB EXT 1990*	URB EXT 2000*	FP EXT
Lang_US	0.982	0.32	0.553	2.75	18.9	638	31.69	0.0041 0.0044	0.0013 0.0014	0.154
Lateral_1	0.834	0.32	0.914	2.49 (2.60)	12	634	8.49	0.096 0.104	0.124 0.129	0.1821
Lateral_2	1	0.32	0.945	1.52 (2.50)	9.2	628	6.54	0.325 0.352	0.419 0.435	0.2059
Lang_FW	0.961	0.32	0.683	4.86	15.5	634	23.36	0.044 0.048	0.080 0.083	0.166

* URBEXT1990 and URBEXT2000 were updated to 2019 and the updated values are in red. URBEXT values for Lateral 1 and Lateral 2 were estimated from OS maps.

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	FEH catchment boundaries were taken from FEH online and amended using LiDAR of 1m resolution and LiDAR derived contours every 5m. OS open source watercourses were used to check that pathways and drainage ditches did not cross catchment boundaries. No sewer information was made available to represent the actual area of the urban catchment so it was assumed that the topographic catchment represented this adequately.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	DPLBAR was updated for the Lateral_1 and Lateral_2 and Lang_US catchment sizes once adjustments to the FEH boundaries had been completed using the following equation DPLBAR = AREA^0.548, found in the FEH Volume 5 equation 7.1. The changes to Lang_US and the Lang_FW gauge catchment areas were small and no update was necessary.
Source of URBEXT	URBEXT1990 (updated to represent 2019 value) was used in ReFH method URBEXT2000 (updated to represent 2019 value) used for FEH statistical and ReFH2. For Lateral_1 and Lateral_2 the urban extents were measured from OS maps, as follows: • Lateral 1 urban area = 1.129 km² • Lateral 2 urban area = 3.36 km² These were then used to calculate URBAN fractions and URBEXT using: • URBEXT1990 = URBAN/2.05 • URBEXT2000 = URBAN*0.629
Method for updating of URBEXT	Equation no.6.8 in FEH Vol 5 for URBEXT1990 Equation no.5.5 in the Defra/EA R&D URBEXT Report for URBEXT2000

3 Statistical method

3.1 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, BFIHOST, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	WINFAP 4 was used to identify potential donor sites; however, all the catchments identified were much larger than the subject site catchment and therefore no adjustment was applied. The flow data calculated for the previous Flood Risk Mapping study was also not used, because the rating in the report indicates that the flows are overestimated (see Sections 1.4 and 1.5. Therefore, QMED was estimated using catchment descriptors.

3.2 Donor sites chosen and QMED adjustment factors

QMED was calculated by catchment descriptors as there were no suitable donor sites – see above.

3.3 Overview of estimation of QMED at each subject site

QMED was calculated using catchment descriptors as there were no suitable donor sites

Site code	Method	Initial estimate of QMED (m^3/s) Rural	Data transfer						Urban Adjustment Factor	Final estimate of QMED (m^3/s) Urban
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor: Weight	If more than one donor: Weighted average adjustment factor		
Lang_FW	CD	1.041	N/A	N/A	N/A	N/A	N/A	N/A	1.151	1.198

Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?	Yes
Which version of the urban adjustment was used for QMED, and why?	WINFAP-FEH v4

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.

When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added.

When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050**Error! Bookmark not defined.** should be used. If the original FEH equation has been used, say so and give the reason why.

The guidelines recommend great caution in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.8). The adjustment method used in WINFAP-FEH v3.0.003 is likely to overestimate adjustment factors for such catchments. In this case the only reliable flood estimates are likely to be derived from local flow data.

The data transfer procedure is from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.

If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the penultimate column.

3.4 Derivation of pooling groups

The composition of the pooling groups is given in the Annex. Several subject sites may use the same pooling group.

Name of group	**Site code from whose descriptors group was derived**	**Subject site treated as gauged?** (enhanced single site analysis)	**Changes made to default pooling group, with reasons** Note also any sites that were investigated but retained in the group.	**Weighted average L-moments**, L-CV and L-skew, (before urban adjustment)
Lang_FW	Lang_FW	No	**Removed:** 203046 - Chalk 33054 - Chalk 26802 - Chalk 33032 - Chalk 26013 – only 6 years of data 7011 – only 6 years of data 26003 – Chalk NB the subject site catchment is underlain by some permeable rocks, but these are limestone not Chalk. Therefore, Chalk catchments with low SPR values were removed. **Investigated:** 27073 - This is a permeable catchment (Corallian) - because not Chalk it was retained, although SPR is less than 20%. The subject site catchment also contains some permeable geology. NB this catchment has an SPR less than 20% and the permeable adjustment to the growth curve should be applied. However, this is the only site in the final PG with SPR<20% and the adjustment was not applied as it would therefore make only a very small difference to the final flows.	L-CV 0.279 L-skew 0.156

Notes

Pooling groups were derived using the revised procedures from Science Report SC050050 (2008).

The weighted average L-moments, before urban adjustment, can be found at the bottom of the Pooling-group details window in WINFAP-FEH.

3.5 Derivation of flood growth curves at subject sites

Site code	**Method** (SS, P, ESS, J)	**If P, ESS or J, name of pooling group (3.4)**	**Distribution used and reason for choice**	**Note any urban adjustment or permeable adjustment**	**Parameters of distribution** (location, scale and shape) after adjustments	**Growth factor for 100-year return period**
Lang_FW	P	Lang_FW	Generalised Logistic – recommended in WINFAP4	UAF = (1.151), Permeable adjustment not applied.	Location: 1.000 Scale: 0.274 Shape: -0.170	2.904

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments to growth curves should use the version 3 option in WINFAP-FEH: Kjeldsen (2010).

Growth curves were derived using the revised procedures from Science Report SC050050 (2008).

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)								
	2	5	10	20	30	50	75	100	200
Lang_FW	1.20	1.71	2.07	2.45	2.69	3.01	3.28	3.48	4.01

4 Revitalised flood hydrograph (ReFH) method

4.1 Parameters for ReFH model

Site code	**Method:** OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	**Tp (hours)** Time to peak	**C_{max} (mm)** Maximum storage capacity	**BL (hours)** Baseflow lag	**BR** Baseflow recharge
Lang_US	CD	4.303	446.796	43.094	1.313
Lateral_1	CD	4.571	720.143	52.35	2.259
Lateral_2	CD	1.84	743.328	22.186	2.341
Lang_FW	CD	5.547	546.034	47.139	1.649
Brief description of any flood event analysis carried out (further details should be given below or in a project report)			None, at this stage.		

4.2 Design events for ReFH method

All storms were applied consistently with the same seasonal profile, alongside the whole catchment area and duration.

Site code	**Urban or rural**	**Season of design event (summer or winter)**	**Storm duration (hours)**	**Storm area for ARF** (if not catchment area)
Lang_US	Rural	Winter	10.5	-
Lateral_1	Rural	Winter	24.5	-
Lateral_2*	Urban	Winter	11.5	-
Lang_FW	Rural	Winter	15.5	-
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			Yes * Lateral_2 is urbanised and so a summer storm would be recommended. However, the Langford Brook catchment at the sites of interest is classed as rural with respect to the ReFH method and therefore winter storms were used to estimate these inflows.	

4.3 Flood estimates from the ReFH method

Site code	**Flood peak (m^3/s) for the following return periods (in years)***							
	2	**5**	**10**	**20**	**30**	**50**	**75**	**100**
Lang_US**	2.08							5.09
Lateral_1	0.06							0.41
Lateral_2	0.08							0.56
Lang_FW**	1.81							4.71

* Flows at this stage have been reported for the 2-year and 100-year only for comparison with the FEH statistical and ReFH2 flows.
** Flows estimated at Lang_US are higher than the flows downstream at Lang_FW because the percentage runoff is higher.

5 Revitalised flood hydrograph (ReFH2) method

5.1 Parameters for ReFH2 model

Site code	Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	Tp (hours) Time to peak	C_{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
Lang_US	CD	4.925	474.787	45.446	1.352
Lateral_1	CD	5.51	1212.693	60.883	2.417
Lateral_2	CD	14.719	1314.386	87.5	2.512
Lang_FW	CD	7.265	665.51	58.483	1.726
Brief description of any flood event analysis carried out (further details should be given below or in a project report)		None, at this stage.			

5.2 Design events for ReFH2 method

Site code	Urban or rural	Season of design event (summer or winter)*	Storm duration (hours)	Storm area for ARF (if not catchment area)
Lang_US		Winter	8.5	-
Lateral_1		Winter	9.0	
Lateral_2		Winter	22.0	
Lang_FW		Winter	11.0	
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			Yes	

5.3 Flood estimates from the ReFH2 method

Site code	Flood peak (m^3/s) for the following return periods (in years)*							
	2	5	10	20	30	50	75	100
Lang_US	1.62							4.42
Lateral_1	0.31							0.89
Lateral_2	0.33							0.85
Lang_FW	1.38							3.74

* Flows at this stage have been reported for the 2-year and 100-year only for comparison with the FEH statistical and ReFH flows.

6 Flood Risk Mapping Study Comparison

A Flood Risk Mapping Study of Langford Village and Bicester was undertaken in December 2009 (Project Ref 15945/006) for the Environment Agency, Thames Region (West Area). This study included Langford Brook.

To summarise, the 2009 study:

- Developed rating curves at 2 flood warning level gauges (Langford Village and Bicester) using the hydraulic model. Only the Langford gauge is of interest for this study. These ratings were developed from spot gaugings undertaken at low flows for this study and the ISIS hydraulic model.
- Inflows to the hydraulic model were estimated using the FEH rainfall-runoff and Tp and SPR values were calibrated using the gauge data.
- An FEH Statistical analysis was carried out at the Langford level gauge catchment using pooling groups to create growth curves. QMED was estimated using 3 methods:
    1. Catchment Descriptors – 1.2 m^3/s;
    2. Peaks over threshold (using the level data and rating) – 4.4 m^3/s;
    3. Engineering judgement – 2.25 m^3/s.
- The engineering judgement QMED estimate (i.e. not a method outlined in the FEH volumes or guidance documents) was developed through analysis of 4 years' worth of flood peak data and rainfall records. It was thought that the POT estimate was too high and the Catchment Descriptor (CD) method was inferior to using flood peak data. The engineering judgement QMED estimate was therefore used.
- Design flow hydrographs were calculated using the FEH rainfall-runoff method and then scaled in the model to match the statistical peak flow estimates.

The hydrology section of the reporting stated that extensive discussions were held with Dave Rylands (Environment Agency Thames Region) and the conclusion of these discussions were that the FEH rainfall-runoff method would be used to generate the hydrographs rather than ReFH (not recommended as a method for urban and permeable catchments), with the awareness of limitations and with the recommendation that the hydrology should be reviewed on collection of more hydrometric data and/or release of any new, more appropriate methods.

The FEH Statistical method peak flows adopted for the Flood Risk Mapping Study at the Langford level gauge are summarised below and were used to scale the FEH rainfall runoff hydrographs:

Return period (years)	Peak flow at Langford Flood Warning gauge (m^3/s)
QMED	2.25
5	3.22
20	4.73
50	5.94
100	7.02
1,000	12.03

A comparison of the flows estimated for the Flood Risk Mapping Study and updated flows calculated for this EWR2 study are provided below.

	Peak flow (m^3/s)			
Return period (years)	**PBA Study (2009) Final**	**EWR2 (2019) - FEH Statistical**	**EWR2 (2019) - ReFH2**	**EWR2 (2019) - ReFH**
QMED	2.25	1.2	1.4	1.8
100	7.02	3.5	3.7	4.7

After discussing the results with the Environment Agency, it was agreed that the flows calculated for the Flood Risk Mapping study should be used for the EWR2 project because these are the most conservative.

7 Discussion and summary of results

7.1 Comparison of results from different methods

This table compares peak flows from the chosen method with those from the FEH statistical method at example sites for two key return periods.

Site code	Ratio of peak flow to FEH Statistical peak					
	Return period 2 years			Return period 100 years		
	ReFH	ReFH2	Previous EA study	ReFH	ReFH2	Previous EA study
Lang_FW	1.51	1.15	1.88	1.35	1.07	2.02

7.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	The flows from the previous Environment Agency study will be used to provide the flow estimates for the EWR2 scheme.

7.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	It is assumed that the flows estimated for the Flood Risk Mapping Study are the most representative for the catchment.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	The catchments which flow into Langford Brook from the west are permeable and urban.
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH **3** 12.5 or the factorial standard error from Science Report SC050050 (2008).	N/A Engineering judgement was used to calculate the final QMED value for the Flood Risk Mapping Study.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	The results should only be used for inflows into Langford Brook model being developed to understand the flood risk to the temporary construction compound.
Give any other comments on the study, for example suggestions for additional work.	It would be useful to undertake check gaugings at Langford Brook Flood Warning gauge so that the rating used in the Flood Mapping Study can be updated.

7.4 Checks

Are the results consistent, for example at confluences?	Yes
What do the results imply regarding the return periods of floods during the period of record?	N/A, although a rating was developed at the Flood Warning gauge for the Flood Risk Mapping Study, the flows are not considered to be accurate.

What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	3.12
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	1.71
What range of specific runoffs (l/s/ha) do the results equate to? Are there any inconsistencies?	For the 100-year event, at Langford Flood Warning gauge the 100-year peak flow is 7.02 m^3/s. This gives a flow of 3.9 l/s/ha.
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	The flows calculated for this study using updated methods are lower than the flows calculated for use in the Flood Risk Mapping Study. The Flood Risk Mapping Study flows are preferred.
Are the results compatible with the longer-term flood history?	This will be checked once the flows have been routed through the hydraulic model and modelled levels can be compared with gauged levels.
Describe any other checks on the results	None

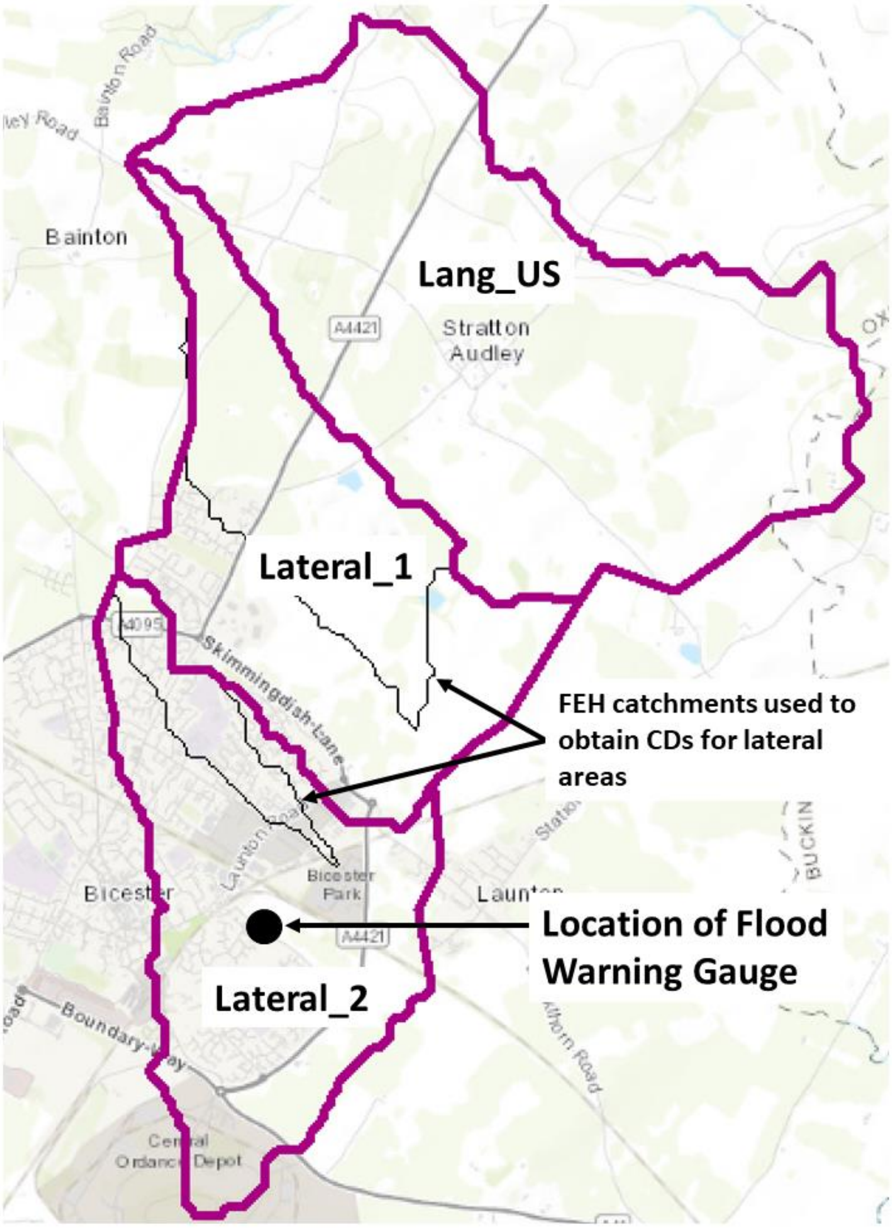
7.5 Final results

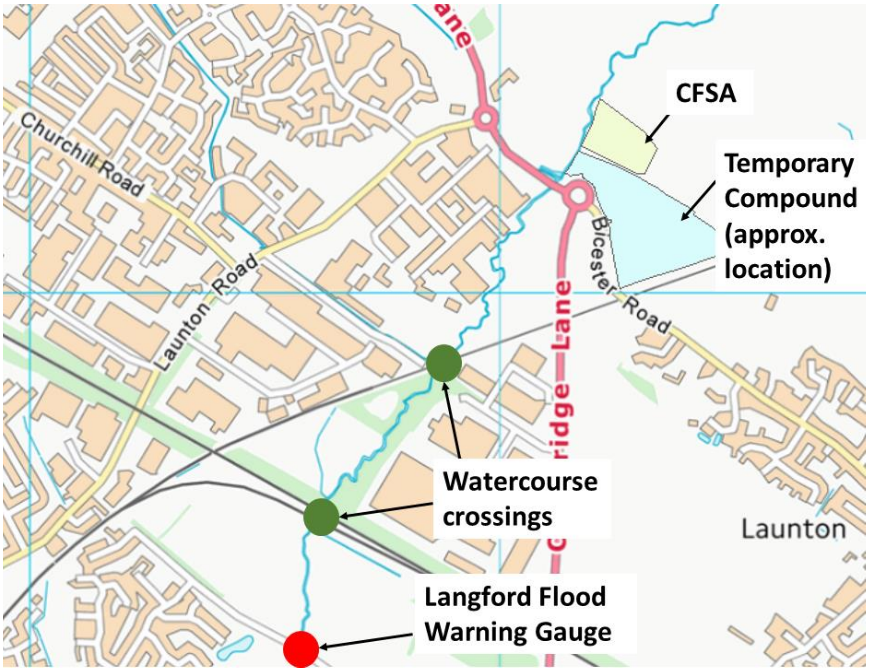
Flows at the Langford Flood Warning gauge are provided below and are taken from the Flood Risk Mapping study. The inflows from this study will also be used as inflows to the EWR2 model.

Site code	**Flood peak (m^3/s) for the following return periods (in years)**							
	2	**5**	**10**	**20**	**30**	**50**	**100**	**1000**
Lang_FW	2.25	3.22		4.73		5.94	7.02	12.03

8 Annex - supporting information

Final catchment boundaries





8.1 Pooling group composition

20002 (West Peffer Burn @ Luffness)
203046 (Rathmore Burn @ Rathmore Bridge)
36010 (Bumpstead Brook @ Broad Green)
41020 (Bevern Stream @ Clappers Bridge)
72014 (Conder @ Galgate)
73015 (Keer @ High Keer Weir)
25019 (Leven @ Easby)
36003 (Box @ Polstead)
36004 (Chad Brook @ Long Melford)
26803 (Water Forlornes @ Driffield)
36007 (Belchamp Brook @ Bardfield Bridge)
34005 (Tud @ Costessey Park)

Appendix F. Langford Brook Hydraulic Model Improvements

Contents

Section **Page**

Tables

Figures

1. Introduction

This Appendix documents the hydraulic model updates and checks made to the Langford Brook hydrological and hydraulic model in response to the Environment Agency review comments. The updates and responses were discussed and agreed with the Environment Agency during meetings on 7th and 16th July 2020.

The nature of the watercourse in the area is split into several discrete flood cells by the various roads and rail embankments that cross it throughout the Langford Brook area. Each flood cell operates largely independently of each other with overtopping events observed only during the highest flow events. As such the model is largely volume driven with the primary hydraulic control formed by each structure under a road or embankment between the flood cells. Due to this physical system works or uncertainties impacting flooding in one flood cell are unlikely to have a significant impact in other flood cells.

The objective of the modelling is to assess the potential impact of the proposed EWR2 works and size and design the CFSA required to compensate for floodplain losses as a result of the EWR2 works.

2. Hydraulic Model Improvements

This section sets out the improvements made to the hydraulic model in response to the Environment Agency review comments. The table below sets out the key improvements made to the model.

Table 2-1 Hydraulic model improvements

No.	Description
1	The model has been trimmed to Langford Brook only. The existing upstream extent is retained. The model is now 1D/2D from the upstream extent down to Gavray Drive. This location is selected as it does not overtop in the higher return periods. Downstream of Gavray Drive there is a short reach modelled using 1D extended sections.
2	2D Roughness has been updated using more recent and detailed Mastermap. Values for the roughness have been derived from FM guidance, other than Inland water which has been lowered to 0.02 and Rail which has increased to 0.05 using modelling judgement. Roughness polygons of same roughness have been merged to speed up processing.
3	Inflows for the trimmed model have been removed from the IED files. There was a lateral inflow (LA.3_IN) which was split across the trimmed model reach with one connection into the trimmed reach, which had a weighting of 0.4. In the trimmed model, the weighting has been changed to 1 and the existing scaling factor in the IEDs has been multiplied by 0.4 to get the correct inflow as per previous model.
4	The downstream boundary has been changed to a normal depth boundary with a specific bed slope take from the slow of the downstream reach in the previous model (between nodes LA.2190 and LA.2773).
5	Interpolate sections have been added where required to aid stability and improve mass balance errors at 1D/2D link.
6	Timestep has been adjusted, 2D 1 sec, 1D 0.5 sec as per Environment Agency Request.
7	Double precision version of FM engine has been used. This reduced the observed 1D mass balance error.
8	Where applicable the orifice units used to model pipes have been changed to circular (old model built in old version of ISIS, where orifice assumed rectangular and changed invert,

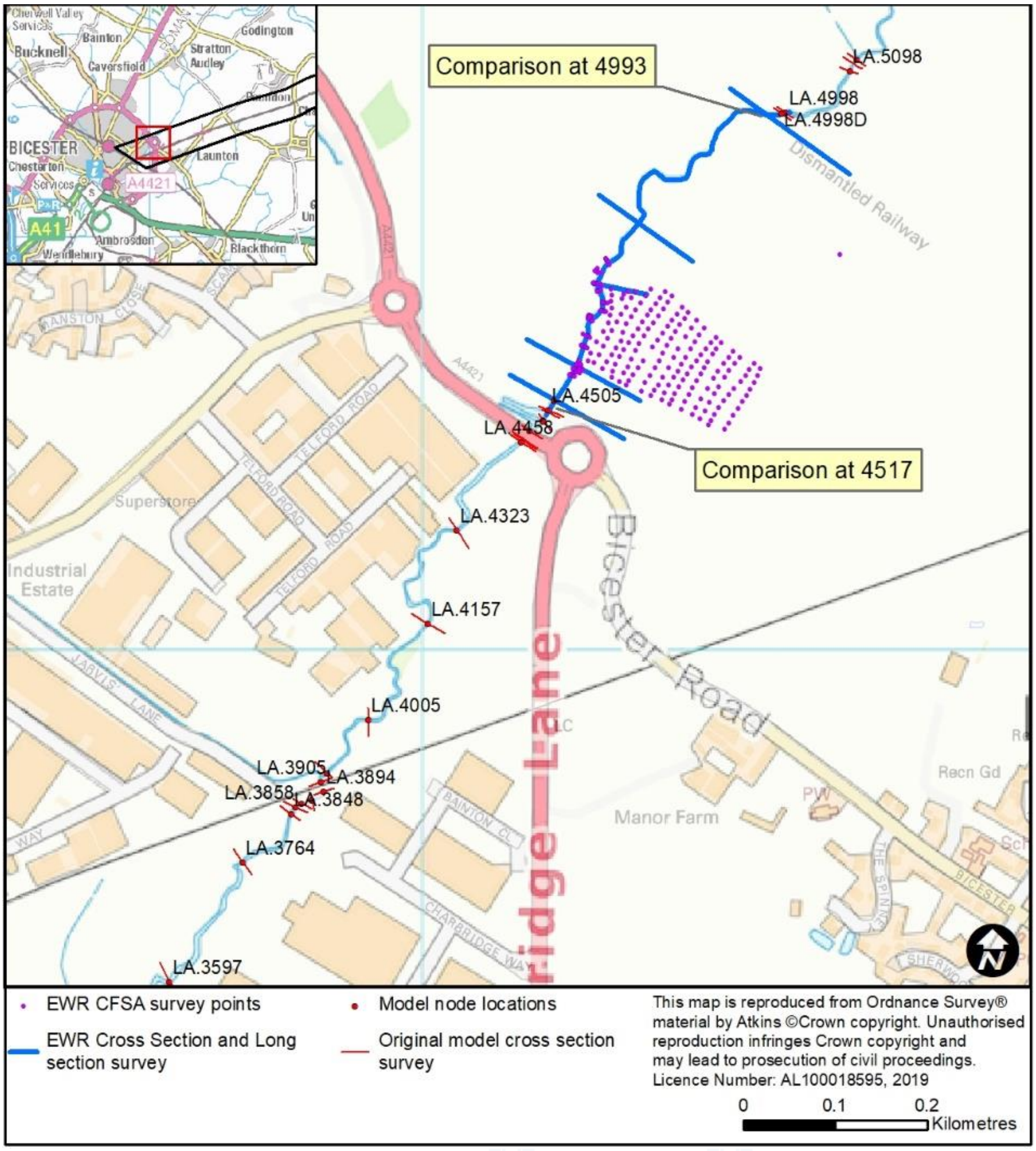
No.	Description
	throat and sill levels to be the same). They varied in the previous model and there was no evidence to support this in the survey. It may have been to aid stability.
9	Changed the modular ratio of orifices to 0.5 to aid stability. Sensitivity test show no impact on results.
10	Re-schematised the model and cross section arrangement upstream of A4421 road bridge. The channel width varies over a short distance and the changes in conveyance led to model instability. The model has been amended following a further review of the topographic data to ensure that the reach is representative of the greater channel conveyance through this reach.
11	To reduce mass balance error at the 1D/2D link, localised areas of increased roughness have been applied. The DTM has also been amended slightly where watercourse joins the main channel as low spots in the bank from LiDAR was causing instability.
12	Changed cross sections at the upstream and downstream face of 3 structures following a further review of topo data. Section data included embankment elevations which meant the capacity of the reach was not represented correctly (i.e. wide section to narrow section). Where this is the case, section data from the upstream section was copied into the incorrect section, and bed level adjusted to match surveyed bed at structure inlet.
13	Trimmed bridge data in bridge units - Section data was extended which was causing convergence issues (afflux calcs would be off).
14	Changed orientation of the 1D/2D boundary lines and added vertices where need to try and align with the bank, this has required some interpretation as for the majority of the model there is no formal bank top/defence.
15	Added Z points to HX lines from new orientation.
16	The model now utilises the 200mm resolution EWR2 project LiDAR, which has mean that the Z lines representing bank top are no longer required.

The subsequent sections provide further detail of the updates and checks made as discussed and agreed with the Environment Agency.

Topographic Survey

The figure below shows the locations of the original cross sections (in red) and the latest cross sections taken as part of the survey for the EWR scheme in blue with the purple points showing the coverage of the CFSA area topographic survey. The new topographic data is made up of 5 cross sections and a ground survey taken throughout the reach where the proposed CFSA will be located. Due to quality issues with the new cross sections found following a review of the new data not all of the data has been utilised within the model.

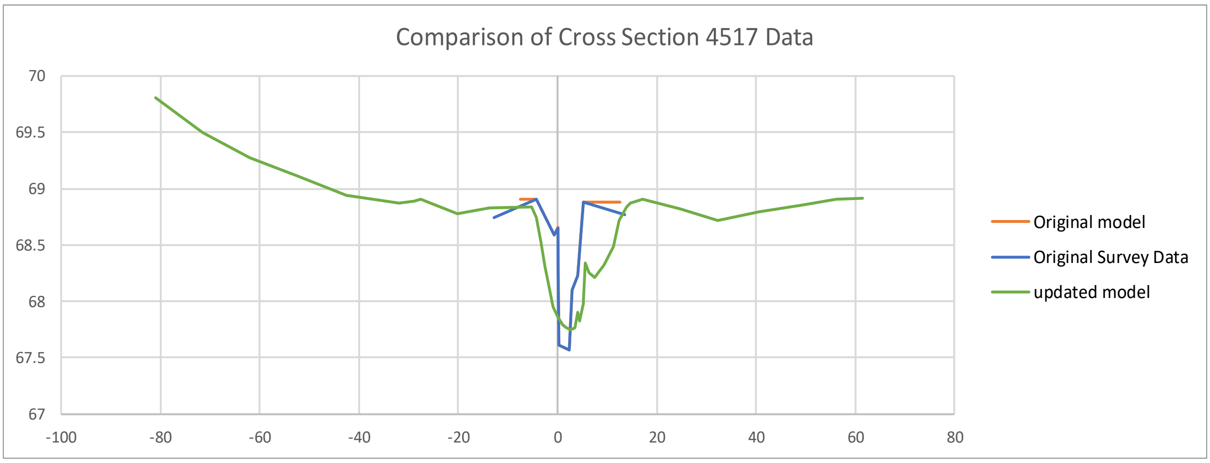
Figure 2-1 Locations of old and new topographic survey data



The in channel cross section 4993 was not surveyed due to safety concerns by the survey team with the following note made by the surveyors: *“Watercourse not surveyed as unsafe to entre due to movement of traffic”.*

The cross section at model node 4517 has not been included. The section at this location includes the presence of an adjacent water feature believed to be a disused cow or sheep dip. This feature rapidly widens the channel as shown in Figure 2-2 below and constricts is again several meters downstream causing instability issues within the model if included. As it is has little hydraulic significance and is not representative of the wider river reach it is considered a suitable simplification to exclude this cross section from the model.

Figure 2-2 Comparisons of topographic data



There are some node spacing errors still when the Model Check tool is run. The Alliance does not have additional topographic survey to add sections to the model in these areas. However, we have undertaken checks to ensure that the model is stable and added interpolates where required. We have not added interpolates elsewhere if the model is stable. Generally the channel is uniform in dimension/conveyance and slope and as the modelled reach is not steep, the mechanism of flooding is within discrete flood cells (flood levels determined by structure capacity and rail embankment heights), and the 1D modelled reach is almost entirely rural in nature, we believe the approach adopted is suitable, as discussed and agreed at meeting on 7th July 2020.

The EWR2 embankment was represented in the incoming model as a simple Z line, the updated 2020 model has improved this representation by replacing the Z line with the project specific 0.2m LiDAR data. This LiDAR data has a native resolution of 0.2m and has been flown for approximately a couple of hundred metres both sides of the embankment. This now utilises a better dataset with more accurate flow path data in the 2D domain.

Structure Coefficients

The original survey data has been checked against the sections, structures and spills to ensure they are represented correctly. Some minor changes have been made (description can be found in the dat file comments) to ensure cross sections are representative of the channel reach as a whole.

The Structure coefficients of the spills in the table below were changed from default values in the original 2009 model. No indication of why these were altered in the original modelling report beyond the following quote:

“Generally the model has been well constructed with appropriate spill coefficients”

The Flood Modeller manual states Weir coefficients ranging from 0.8 to 1.2 are within a normal range. To provide evidence that these have been suitably chosen and not impacting the results beyond use as a calibration parameter; a sensitivity test has been undertaken to better understand the changes made to the original model.

Table 2-2, below shows the approximate increase in flows over the spills due to the change in coefficients during a 1% annual chance event.

Table 2-2 Spill coefficients test results

Spill node	Flow increase at 1% annual chance event using default values of 0.9 and 1.2 (m^3/s)
LA.5527SU (modular limit 0.9 and weir coefficient of 0.8)	0.2
LA.4493SU (modular limit 0.9 and weir coefficient of 1)	0.12
LA.4474SU (modular limit 0.9 and weir coefficient of 1)	N/A – does not spill
LA.3905SU (modular limit 0.9 and weir coefficient of 1)	N/A – does not spill
LA.3865SU (modular limit 0.9 and weir coefficient of 1)	0.06
LA.3503SU (modular limit 0.9 and weir coefficient of 1)	0.05

The hydrographs below show the results of the sensitivity test on water levels at the CFSA location and at the location of the temporary diversion road respectively. In both cases there is under a 3mm difference in peak water levels. As such the model is insensitive to changes in spill weir coefficients and these have been left as they are in the original model.

Based on the reduction in weir coefficient the original model was attempting to represent a less efficient spill over the structures but still within the recommended range. This is consistent with aerial and site photographs that show vegetation surrounding the channel which will impede flows.

Figure 2-3 1% annual chance event - Coefficient sensitivity - CFSA location (green represents original Environment Agency model)

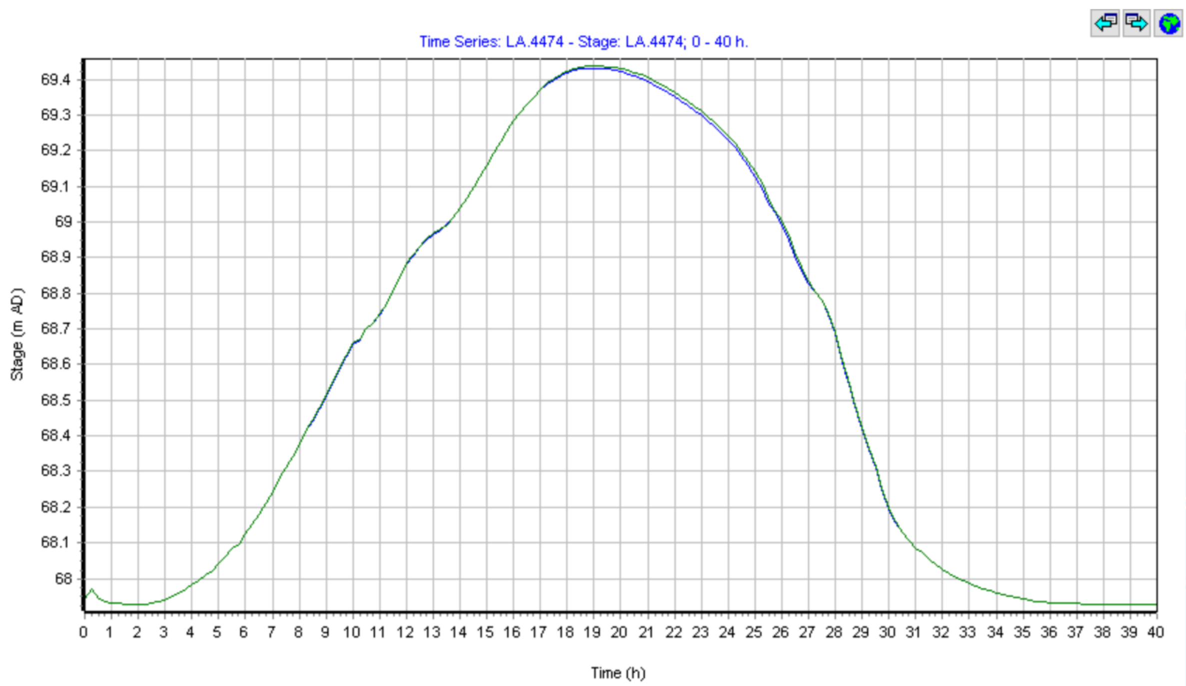


Figure 2-4 1% annual chance event - Coefficient sensitivity - temporary diversion road location (green represents original Environment Agency model)

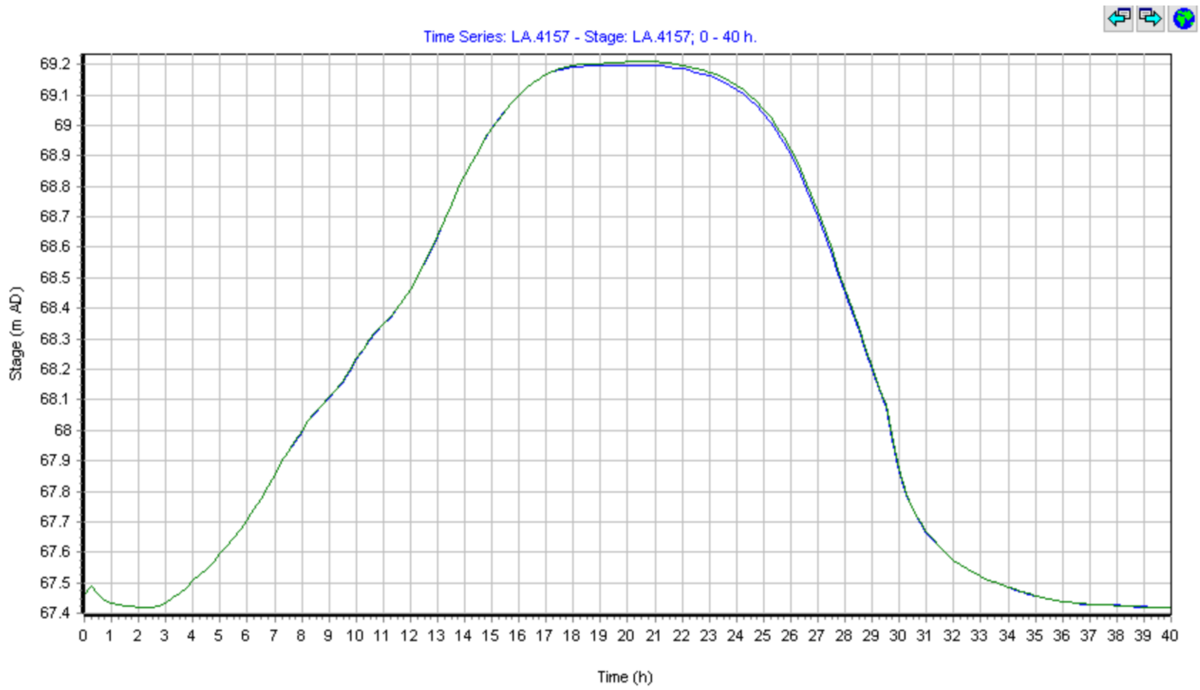
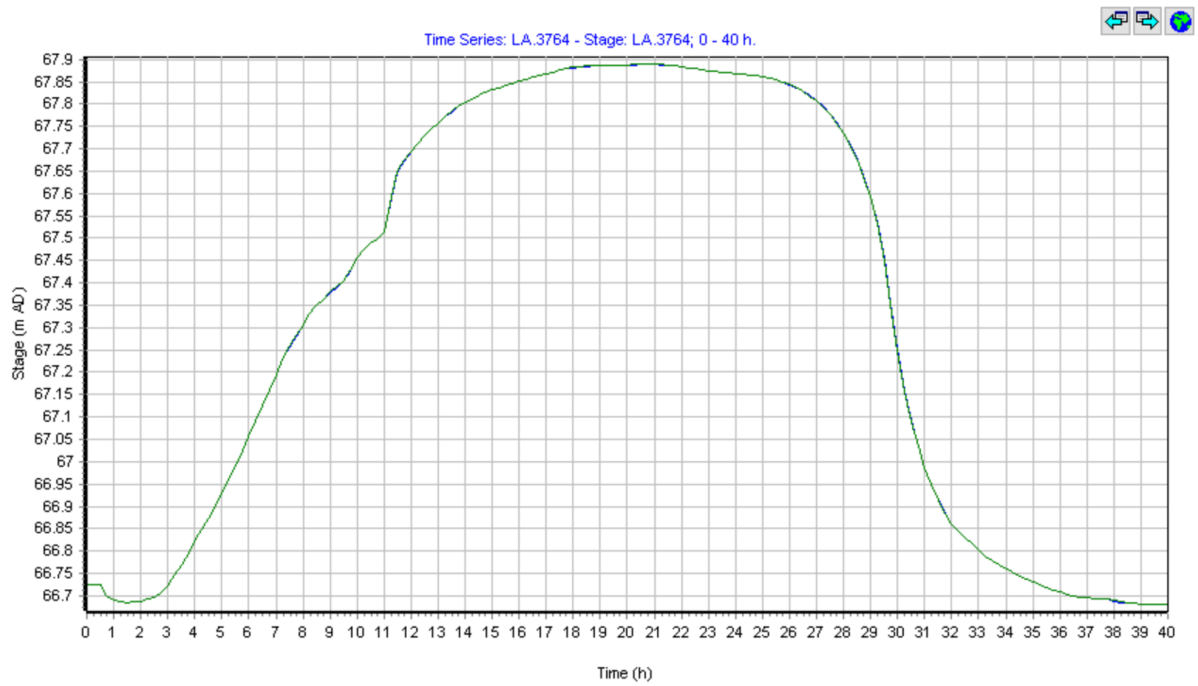


Figure 2-5 1% annual chance event - Coefficient sensitivity - downstream of EWR2 embankment (green represents original Environment Agency model)



Mannings Roughness

The model roughness values were derived from the original model, described in the 2009 report:

"*Roughness (Manning's 'n') coefficients have been set to 0.05 for in-channel flow and 0.06 for out of bank flow for the Bure/Back Brook and Pingle Stream. The Langford Brook roughness values have been set to the same values, following further site investigation, review of photographs, and calibration and validation*"

The table below shows Photographs taken at the time of survey in 2007 and the latest survey undertaken for EWR in June 2019. Both photographs show the same river reach between the dismantled railway and the Charbridge Lane roundabout. Despite the different seasons, the photographs show a similar level of roughness in and surrounding the Langford Brook channel throughout the study area. Based on this evidence it has been concluded that the original model roughness values are still suitable and representative of the environment and therefore do not require updating for the EWR2 study.

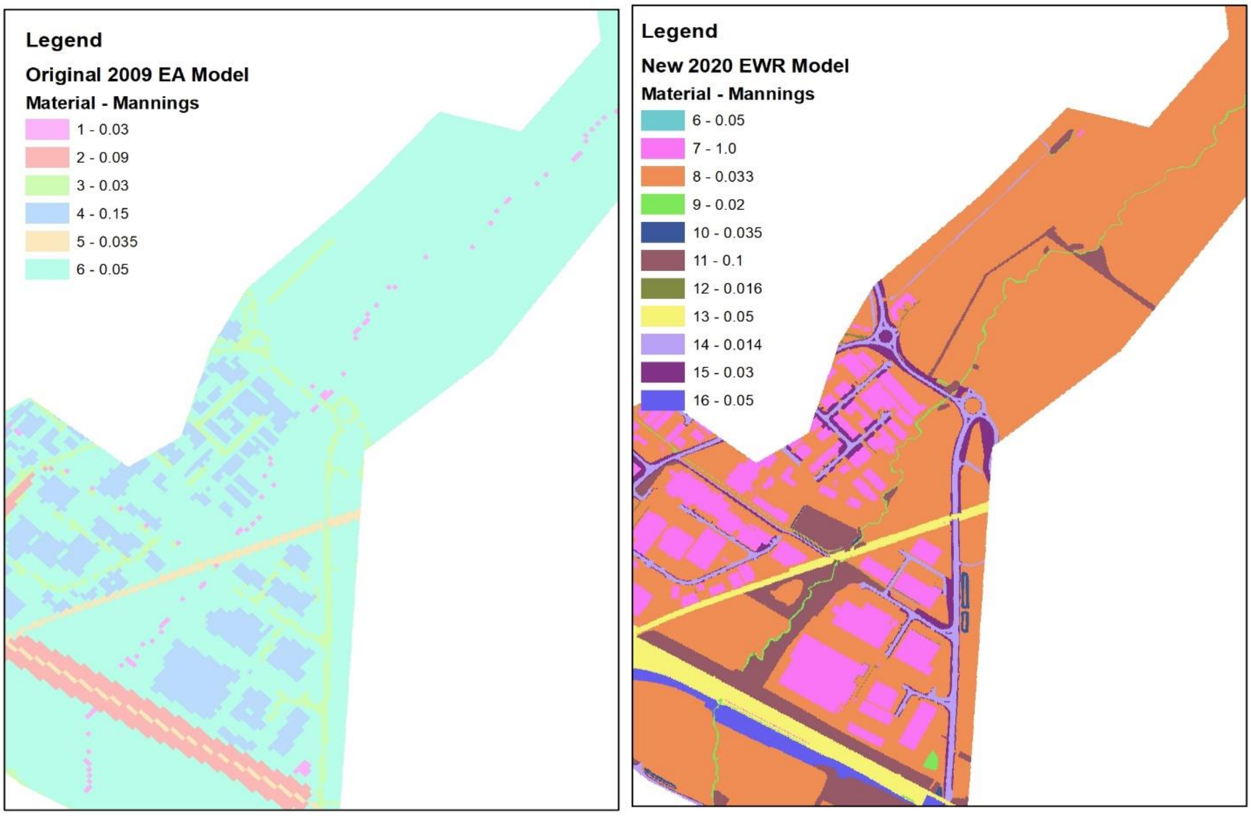
Figure 2-6 Mannings roughness comparison

Photograph of Langford Brook on river reach upstream of Model Cross Section 4517, taken June 2019.	Photograph of Langford Brook on river reach upstream of Model Cross Section 4517, taken Feb-April 2007.
	

The Manning's values for the 2D model domain have been updated using Ordnance Survey MasterMap data in line with updating the models resolution to 2m. Values for buildings have been changed to 1.0 as per FM guidance. Inland water is usually high to account for vegetation which may be on the surface but has been lowered slightly to 0.02. For rail there are no detailed polygons in the Mastermap dataset, so we cannot differentiate between track, ballast and embankment. We think that the value of 0.03 is too low so we have increased to 0.05 for a combined representation. A visualisation of the Mannings values used is shown below in Figure 2-7.

A +/-20% manning sensitivity has been undertaken changing both floodplain and in-channel roughness values, this shows approximately 20mm variation in in-channel levels in the flood cell upstream of the EWR2 embankment, shown in the figure pasted below.

Figure 2-7 Mannings roughness update



Hydrology

The hydrology is consistent with the original 2009 assessment as described in Section 5 of the 2009 model report. Updated hydrology was undertaken for the EWR2 project with the FEH proforma provided using the latest methods (see Appendix E). However, these estimates gave significantly lower flows than the 2009 study, therefore it was agreed with the Environment Agency that the older hydrology would be used as a conservative estimate.

The inflow boundaries have therefore not been changed from the 2009 model, with the exception of the adjustment of the lateral inflow (LA.3_IN) to account for the truncated model reach.

Model truncation and downstream boundary

The model has been truncated and a new downstream boundary has been added upstream of the Langford Brook confluence with other watercourses. The model has been limited to Langford Brook only and the model is fully 1D/2D down to Gavray Drive as shown in Figure 2-8, below. This location was selected as flow does not overtop the road at this location so it is a logical place to end the 2D domain. A short reach downstream of Gavray Drive culvert has been modelled using extended 1D sections. This location is approximately 400m downstream of the 2D boundary and 1km downstream of the study area therefore will not affect flood levels in the EWR2 area, as demonstrated through our sensitivity tests.

A long section showing the baseline 1% annual chance event maximum stage alongside a sensitivity analysis using a +50% and -50% change in downstream boundary slope has been pasted below this table to show the impacts of any uncertainties in the downstream boundary in this area. The long section shows changes to the downstream boundary are largely restricted to the 1D run-out section of the model where variations of 20mm can be seen at the upstream part of this flood cell, approximately 400m from the downstream boundary. The flood cell upstream of this shows it is much less sensitive to changes in boundary conditions with variations around 2mm at the start of the long section. The results of this sensitivity test supports the volume driven nature of the model with the structures at the end of each hydraulic cell controlling the conveyance through the system with each cell having little impact on the ones upstream of it.

Figure 2-8 Updated Model Boundary

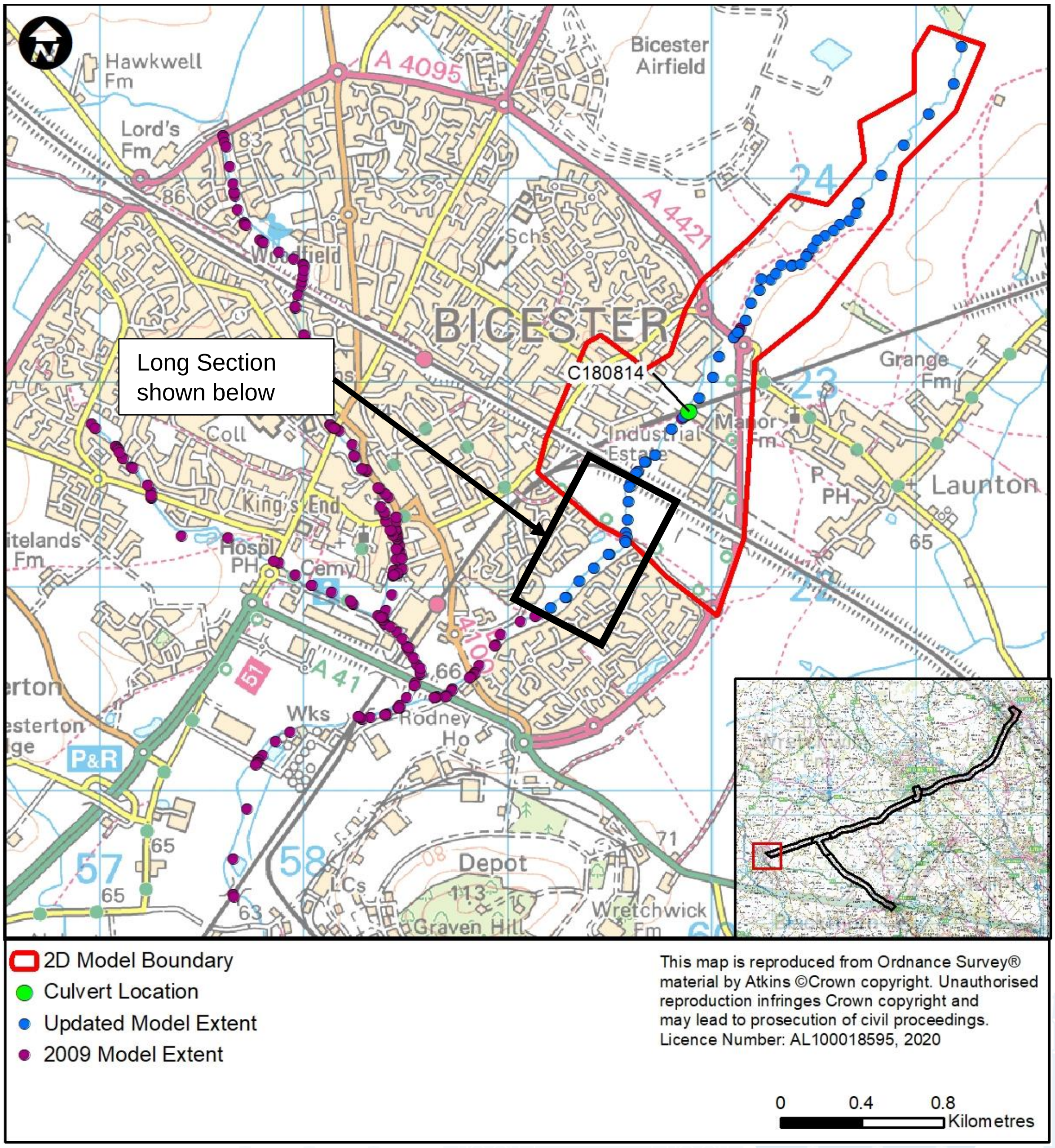
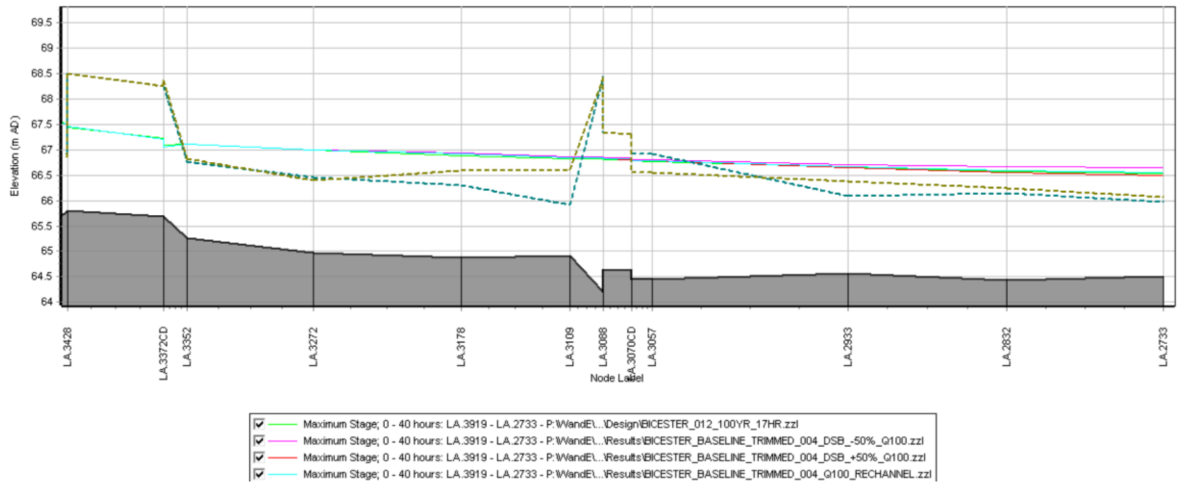
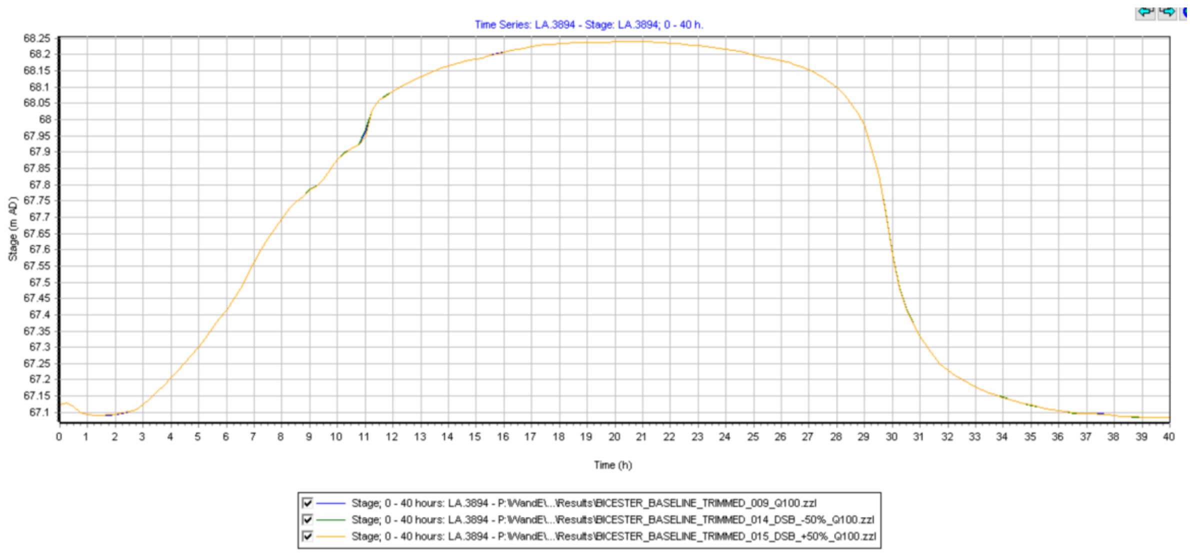


Figure 2-9 Updated 1D downstream boundary sensitivity results – long section



The figure below shows the stage hydrographs for the sensitivity tests at the location just downstream of the EWR2 embankment, and demonstrates limited impact of changes to the downstream boundary on the stage hydrograph at this location and negligible impact on the peak.

Figure 2-10 Updated 1D downstream boundary sensitivity results – stage hydrographs



Model Run Parameters

The model timesteps have been changed in line with the Environment Agency review comments, as set out in the table below. The new timesteps are line with the reduced cell size of the model. The model run time has not significantly changed due to the reduction in 2D Domain with most runs completed within approximately 12-hours. The double precision version of Flood Modeller was used in order to help reduce mass balance errors at the 1D-2D link.

A new initial condition file called “Bicester_Baseline_Trimmed_001.iic” was developed and used in all runs to provide a more stable starting point for the model.

Table 2-3 New model timesteps in EWR Langford Brook study

Domain	Original 2009 model timestep (seconds)	EWR study model timestep (seconds)
1D	2	2
2D 2m	n/a	1
2D 10m	4	4

Model Stability

We have significantly improved the 1D convergence. By trimming the model we were able to focus on the study area. We have made changes such as amending schematisation, changing 1D/2D boundary connections, adding interpolates, and using the double precision version of FM TUFLOW.

Warnings / Error Messages and explanations

- NoXY WARNING 2218 - Manning's n value of 1. for Material 7 is unusually low or high: This value has been used for the buildings as discussed in other comments in line with FM guidance.
- CHECK 2099 also appears several times in the spatial diagnostics file where the repeat application of the 2D boundary occurs from the HX line, these are all located at cross sections along a continuous river reach and therefore will not impact the model schematisation.
- Warning: 12 node labels missing from the initial conditions: no impact on model stability at run time.
- 3 x *** warning W2302 *** time to peak, 7.228, is not an integer multiple of the data interval, 0.500: as agreed no changes to the hydrology.
- Warning: different values (+/- 20%) for Mannings n encountered within one panel: insignificant impact on conveyance/stage/flow.
- Multiple *** warning W2229 *** Value of trash screen height is set to 0; areas will be calculated using piezometric head: no trash screens present on structures.

Model Performance

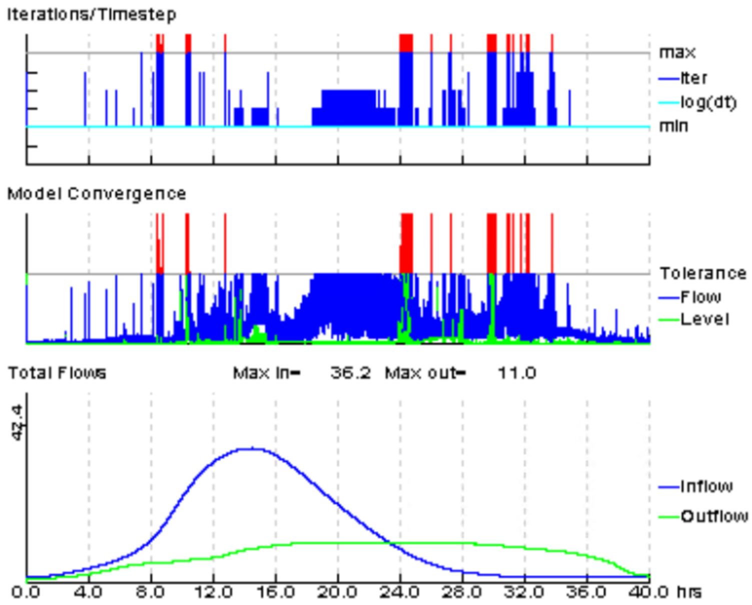
Model stability has been improved following updates made to the model. To provide further confidence in the model results despite some mass balance errors remaining around the 1D-2D linkage a simulation has been run in using the HPC solver, this is a fully mass conserving solver and therefore prevents mass balance issues from impacting the model results directly. The results of this sensitivity are shown below (upstream of the EWR2 embankment) and can be seen to have up to a 7mm impact on results at the peak (1% annual chance event).

As the HPC scheme is fully mass conserving it can mask problematic areas in the model with little indication in the final outputs. A good health check on this situation is to check the adaptive timesteps determined by the solver throughout the run to ensure these are sensible. The "efficiency" metric can also be used but as the Langford Brook model is 1D-2D linked this is a much less meaningful statistic. The figure below shows the timesteps used throughout the HPC run. The graph shows timesteps starting at 0.1 seconds (the default as no initial timestep was set in the tcf file) then rising quickly to 0.5 seconds during the rising limb of the hydrograph, lowering to 0.25 during the peak and back to 0.5 for the receding limb. This is fairly constant with the timesteps used in Tuflow classic and as such shows the run is suitable for the purposes of a sensitivity.

There are some non-convergence issues at very high flows seen in the 1% annual chance event plus 70% climate change and 0.1% annual chance events for the rising and receding hydrograph. These are both found only at the bridge structure LA.3503BU where some backflow begins over this structure (downstream of the EWR2 works). This occurs when ponding from the downstream embankment reaches the structure creating a flat water suffice which can be clearly seen in long sections for these events.

The figures below show how the FM run plot for the 1% annual chance event plus 70% climate change has been improved, comparing the 2009 model (Figure 2-11) and the updated 2020 model (Figure 2-12).

Figure 2-11 2009 Model FM Run Plot



Datafile: ...\DESIGN\BICESTER_012_100YRCC_17HR_70%.DAT
Results: ...\RESULTS\BICESTER_012_100YRCC_17HR_70%.zzl
Ran at 10:00:23 on 22/09/2017
Ended at 10:42:39 on 22/09/2017
Start Time: 0.000 hrs
End Time: 40.000 hrs
Timestep: 2.0 secs

Figure 2-12 Updated 2020 Model FM Run Plot

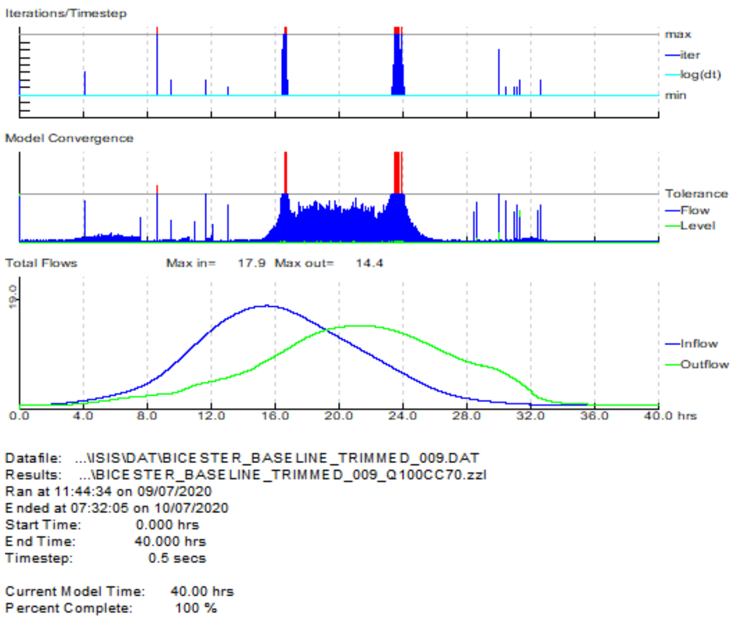
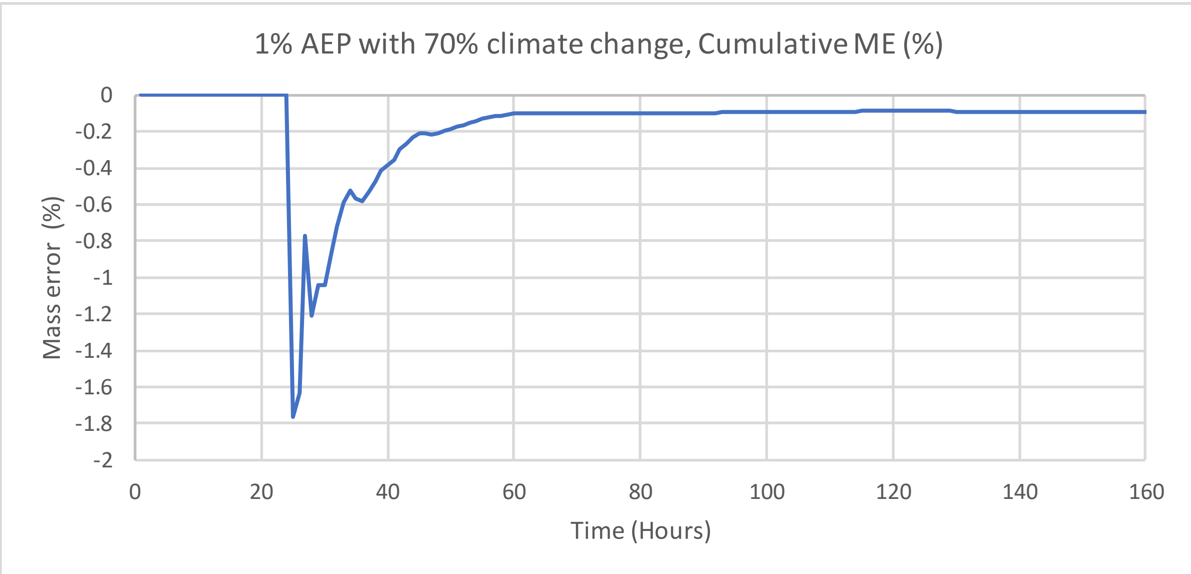


Figure 2-13 shows the mass error reported within the 2D domain for the updated baseline 1% annual chance event with 70% climate change. This figure shows a stable 2D domain throughout the model run following an initial spike when water starts to spill into the 2D domain.

Figure 2-13 1% annual chance event with 70% climate change, Cumulative ME (%)



3. Sensitivity Testing

A range of sensitivity tests on the improved baseline model were undertaken to test the potential impact of uncertainties in the model; the table below lists out the sensitivity tests completed.

Table 3-1 Sensitivity Tests

Sensitivity Test Description	.tcf file name
Showing impact of additional volume in floodplain if LiDAR to east of downstream rail embankment is not correct.	Bicester_Baseline_Trimmed_008_Q100_RetSens.tcf
HPC run to show impact of MB	Bicester_Baseline_Trimmed_009_Q100_HPC.tcf
Single precision run to show impact	Bicester_Baseline_Trimmed_009_Q100_SP.tcf
Showing embankment as original Z line representation	Bicester_Baseline_Trimmed_010_Q100_EmbZSens.tcf
Spill coefficients set to default	Bicester_Baseline_Trimmed_011_Q100_CoefSens.tcf
+20% mannings	Bicester_Baseline_Trimmed_012_Q100_ManP20.tcf
-20% mannings	Bicester_Baseline_Trimmed_013_Q100_ManN20.tcf
-50% downstream boundary slope	Bicester_Baseline_Trimmed_014_DSB_-50%_Q100.tcf
+50% downstream boundary slope	Bicester_Baseline_Trimmed_015_DSB_+50%_Q100.tcf
Modular limit to default on orifices	Bicester_Baseline_Trimmed_016_Q100_ModLimSens.tcf
Using smoothing method of HX-transfer link	Bicester_Baseline_Trimmed_017_Q100_HXFlag.tcf

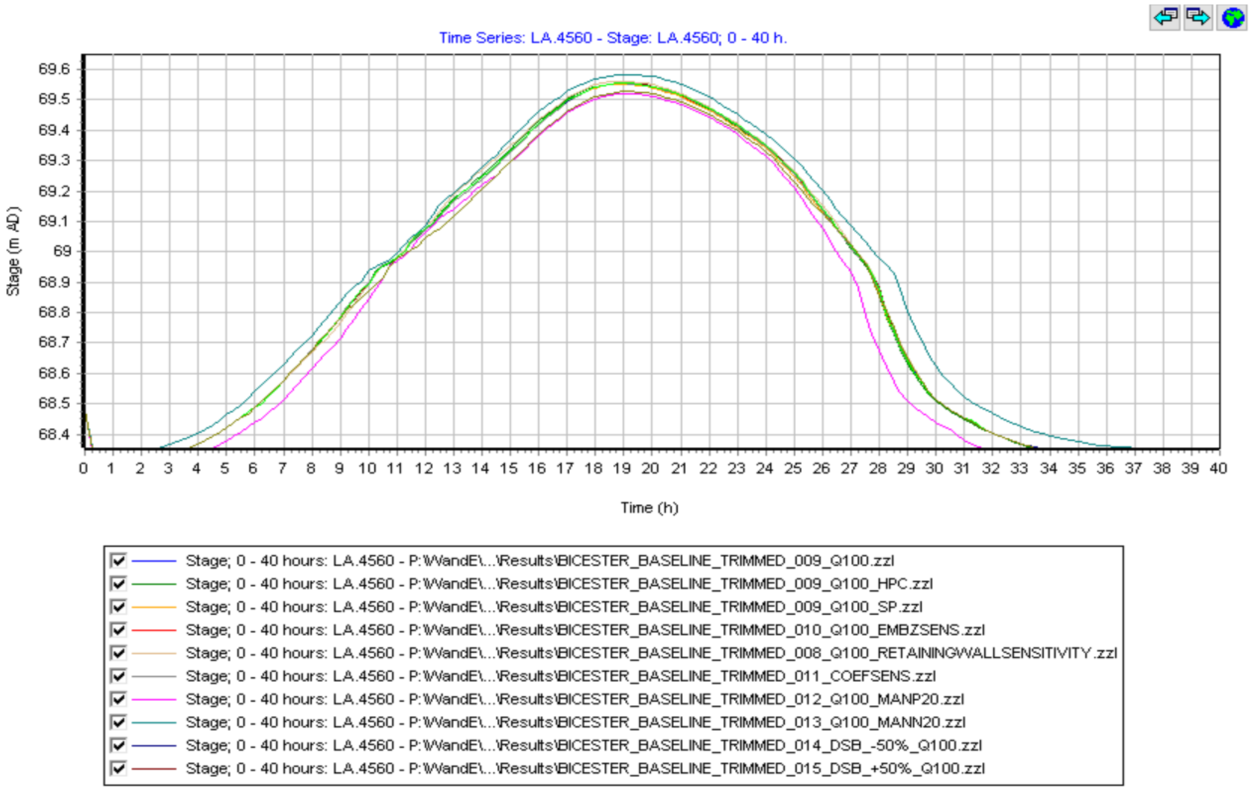
The figures below compare the stage hydrographs for the sensitivity tests at three locations for the 1% annual chance event:

1) Adjacent the proposed EWR2 CFSA (cross section LA.4560)
2) Upstream of the existing EWR2 embankment (cross section LA.4005)
3) Downstream of the existing EWR2 embankment (cross section LA.3858)

Since the sensitivity tests were undertaken minor changes have been made to the model along the EWR2 embankment, however these changes were not of a scale that would influence the outcome of the sensitivity tests.

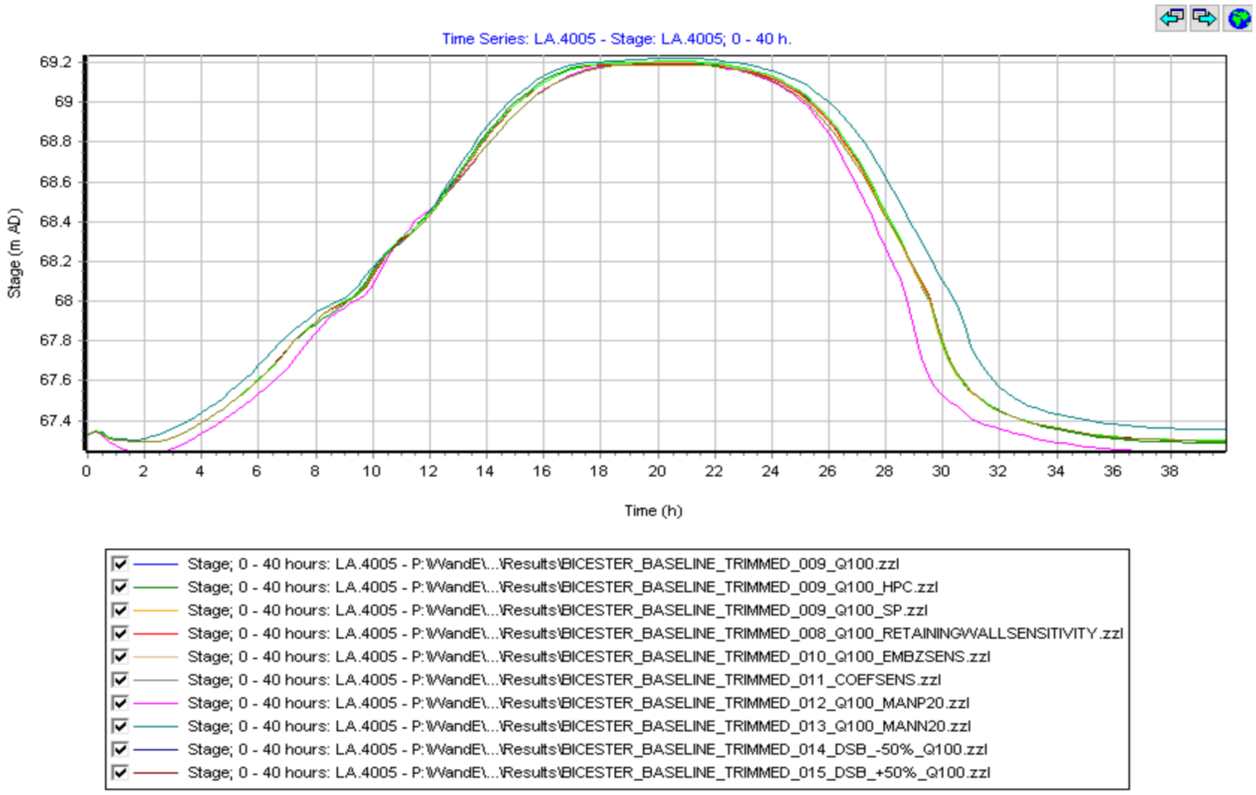
Adjacent to the proposed EWR2 CFSA it is clear that the stage hydrographs are matching in terms of the shape of the hydrographs and timing of the peaks, and with limited differences in peak water level between the different sensitivity tests. Table 3-2 provides a comparison of the peak water levels across all the sensitivity tests at these locations.

Figure 3-1 Comparison of sensitivity test stage hydrographs at the EWR2 CFSA



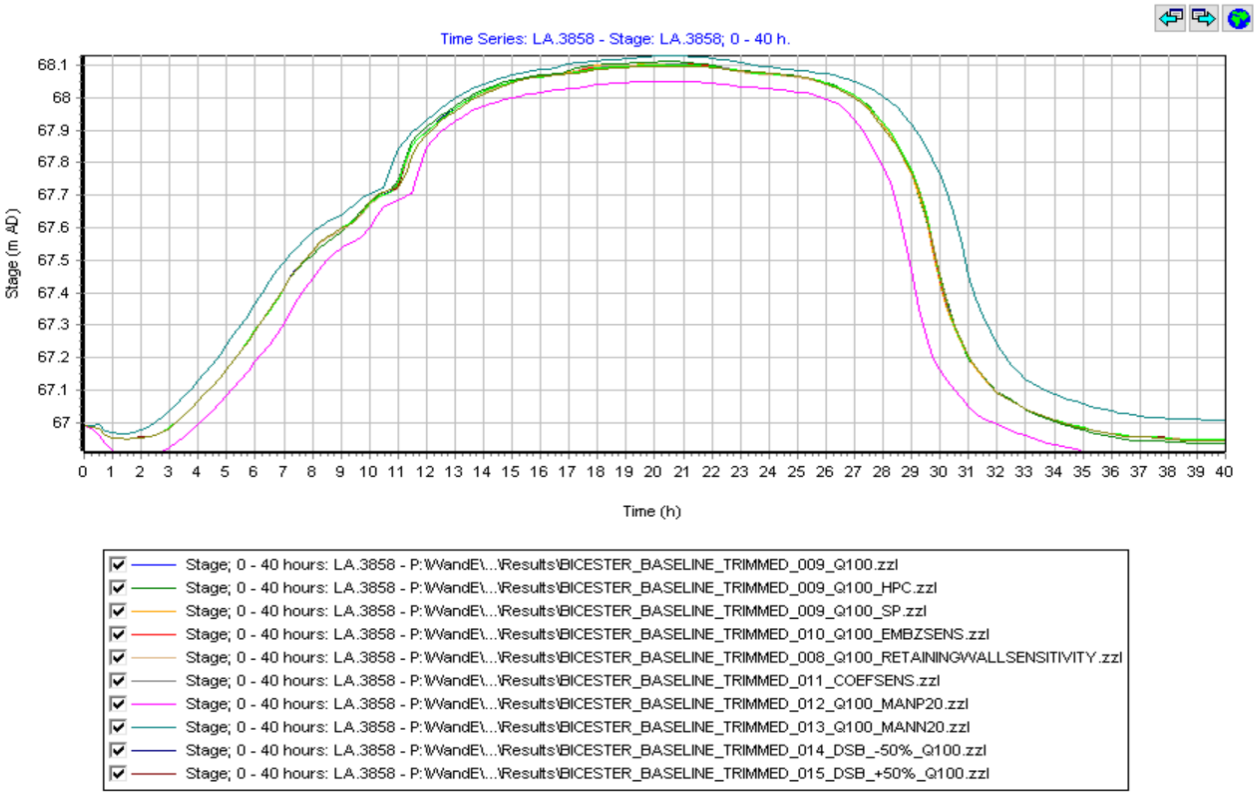
Upstream of the existing EWR2 embankment, as at the proposed CFSA it is clear that the stage hydrographs are matching in terms of the shape of the hydrographs and timing of the peaks, and again have limited differences in peak water level between the different sensitivity tests.

Figure 3-2 Comparison of sensitivity test stage hydrographs upstream of the EWR2 embankment



Downstream of the existing EWR2, as with the two locations upstream the stage hydrographs are matching in terms of the shape of the hydrographs and timing of the peaks, and with limited differences in peak water level between the different sensitivity tests.

Figure 3-3 Comparison of sensitivity test stage hydrographs downstream of the EWR2 embankment



The following table compares the peak water levels for the 1% annual chance event for the sensitivity tests at the three locations described above and confirms the limited differences in peak water level across the range of sensitivity tests in these locations. The largest difference is an increase of 0.09m upstream of the EWR2 embankment for the use of the smoothing method of HX-transfer link; elsewhere maximum changes are +/- 0.04m, with the majority of tests and locations showing no change or change of +/- 0.01m.

Table 3-2 Sensitivity test results comparisons

Scenario	Peak Water Level (mAOD) at 1% annual chance event		
	EWR2 CFSA	Upstream of EWR2 embankment	Downstream of EWR2 embankment
Baseline	69.56	69.21	68.11
Roughness -20%	69.52	69.19	68.09
Roughness +20%	69.58	69.22	68.15
Downstream boundary +50%	69.56	69.21	68.12
Downstream boundary -50%	69.56	69.21	68.12
HPC	69.55	69.20	68.12
Embankment Z line	69.56	69.20	68.12
Retaining wall	69.56	69.21	68.12
Spill coefficients	69.56	69.21	68.12

Scenario	Peak Water Level (mAOD) at 1% annual chance event		
	EWR2 CFSA	Upstream of EWR2 embankment	Downstream of EWR2 embankment
Orifice coefficients	69.55	69.19	68.12
Single precision	69.53	69.19	68.11
HX Flag	69.60	69.30	68.12
50% EWR Blockage	69.56	69.22	68.12
Railway roughness	69.56	69.19	68.12
Retaining wall uncertainty	69.56	69.20	68.12

4. Comparison of results and scenarios

Updated Baseline (2009 model and 2020 Updated Model)

As discussed on the call on 7th July 2020 there are differences between the 2009 model and 2020 updated model, however these are primarily due to the higher model resolution and new EWR2 LiDAR made as part of the model improvements, with general trends remaining broadly consistent with the previous model, although absolute levels have increased slightly over the previous baseline this is due in part to a more robust representation of the EWR2 railway embankment in the baseline model. This representation utilises existing EWR2 survey data in addition to the LiDAR data used in previous model versions, that was found to have instances of poor filtering (ground features not visible in Street View, topographic survey and survey photos).

This section compares the 2009 Environment Agency outputs and the 2020 updated baseline model representation of the existing flood risk.

Comparison of results

The following figures compare the stage hydrographs for the 1% annual chance event at the following locations:

1) Adjacent the proposed EWR2 CFSA (cross section LA.4493)
2) Upstream of the existing EWR2 embankment (cross section LA.4005)
3) Downstream of the existing EWR2 embankment (cross section LA.3858)

These figures show the changes in stage between the 2009 model and the 2020 updated baseline model.

Figure 4-1 Comparison of stage hydrographs at the EWR2 CFSA

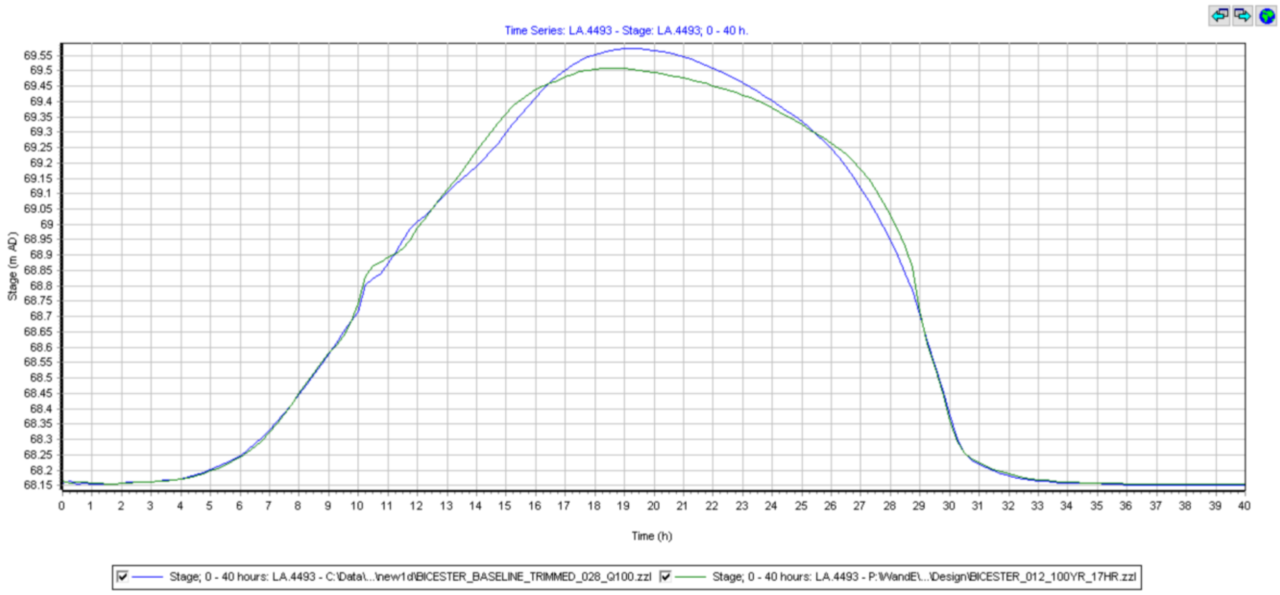


Figure 4-2 Comparison of stage hydrographs upstream of the EWR2 embankment

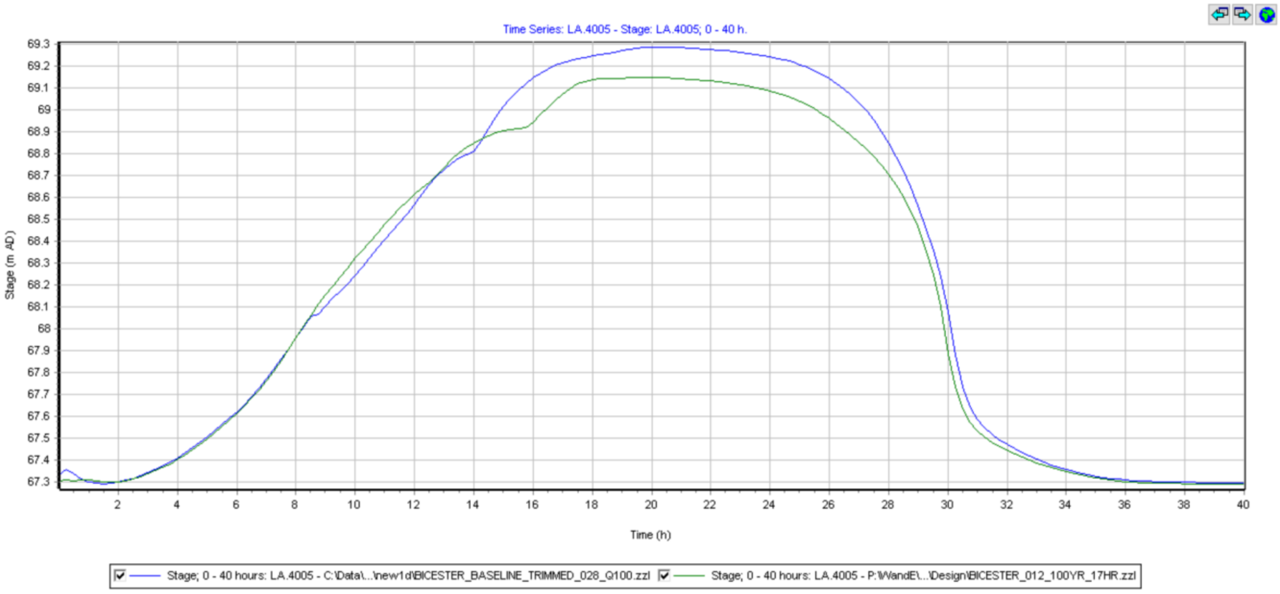
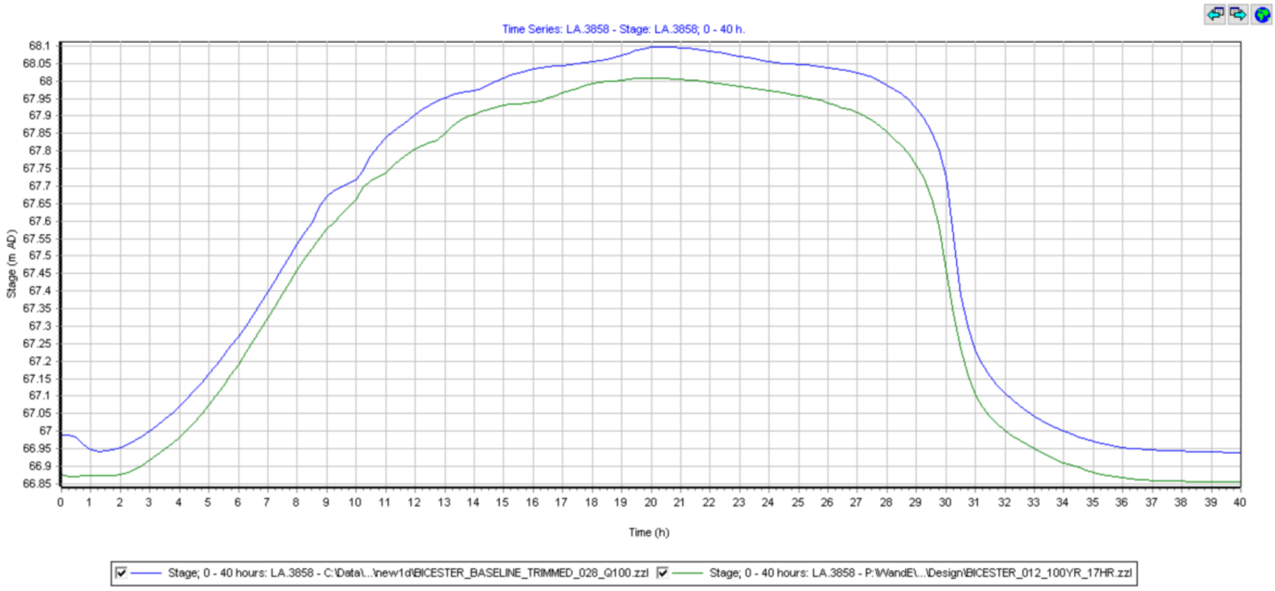


Figure 4-3 Comparison of stage hydrographs downstream of the EWR2 embankment



The following figures compare the 5% annual chance event, 1% annual chance event and 0.1% annual chance event flood outlines and differences in flood levels. The 2020 updated baseline generally suggests larger extents and depths than that predicted by the 2009 model. A comparison between the 1% annual chance event plus climate change allowance was not undertaken since the 2009 model applied a 20% increase whilst the 2020 updated model applies 70%. The figures show differences in both extents and levels for all the events examined, with both increase and decreases in flood depths observed, seeing changes of +/- 0.24-0.1m at the more extreme events (1% and 0.1% annual chance events), this is largely due to the improved model resolution and better representation of the EWR2 embankment.

Figure 4-4 5% annual chance event comparisons

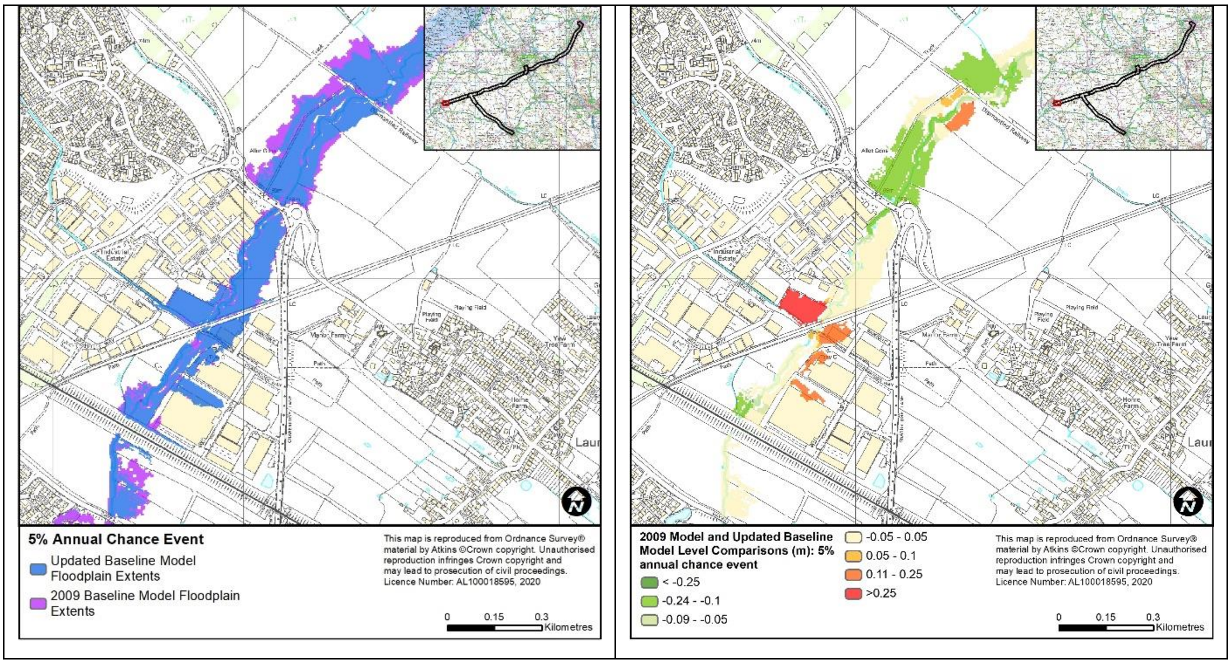


Figure 4-5 1% annual chance event comparisons

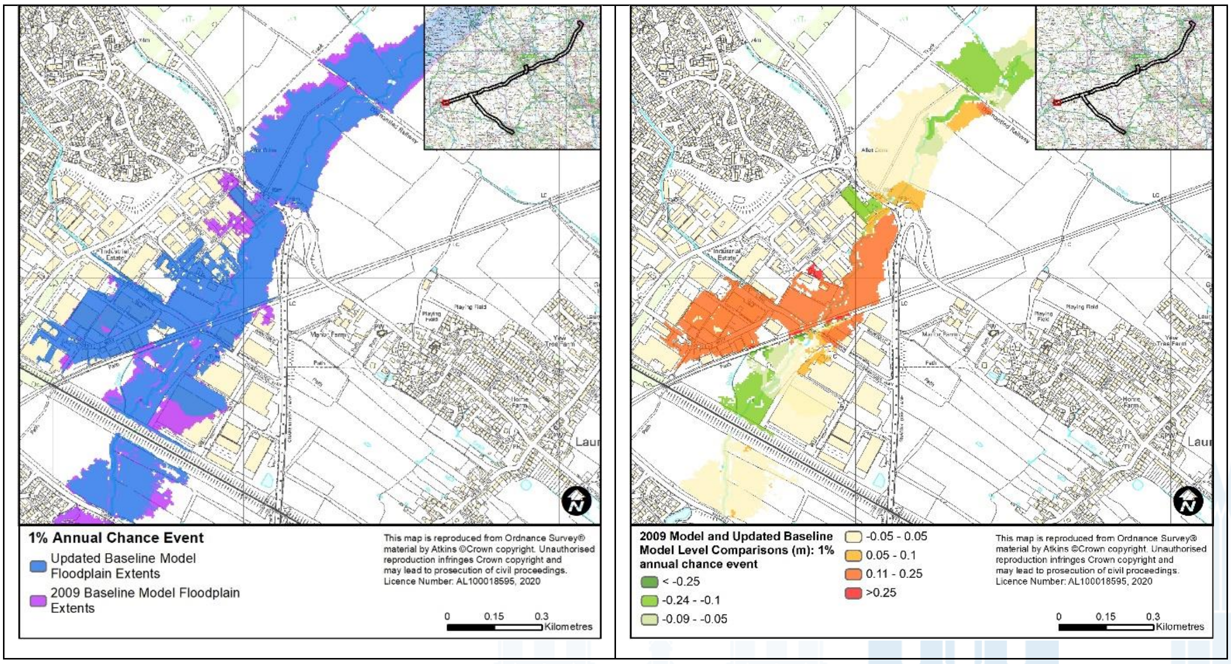
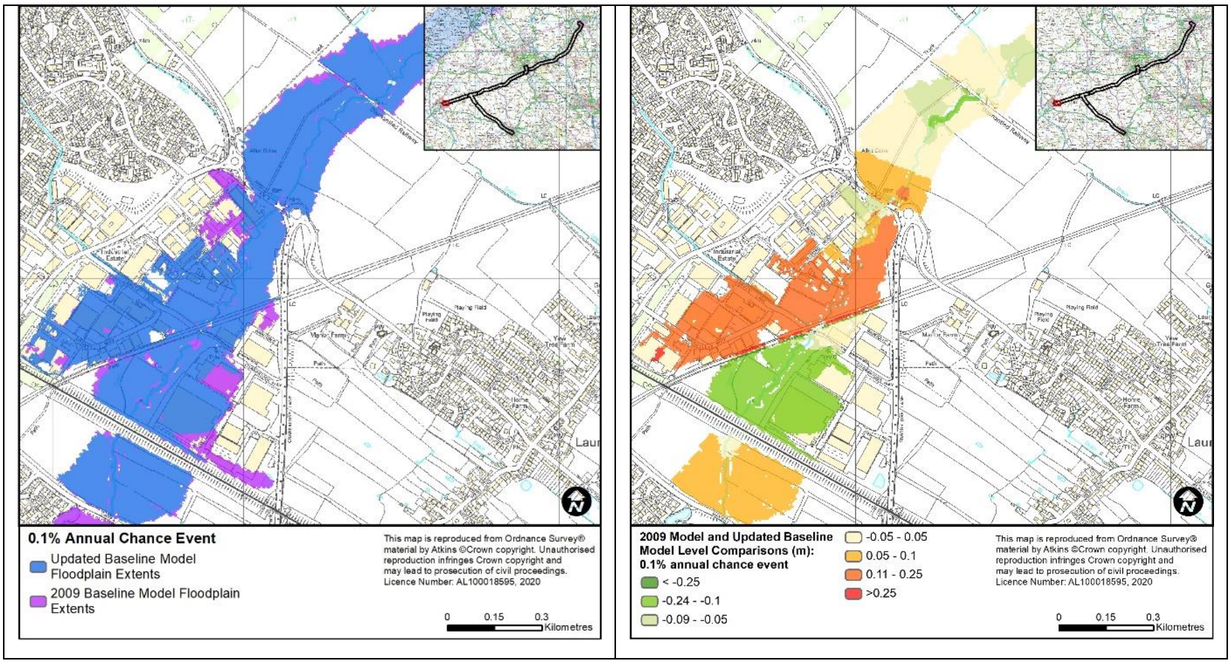
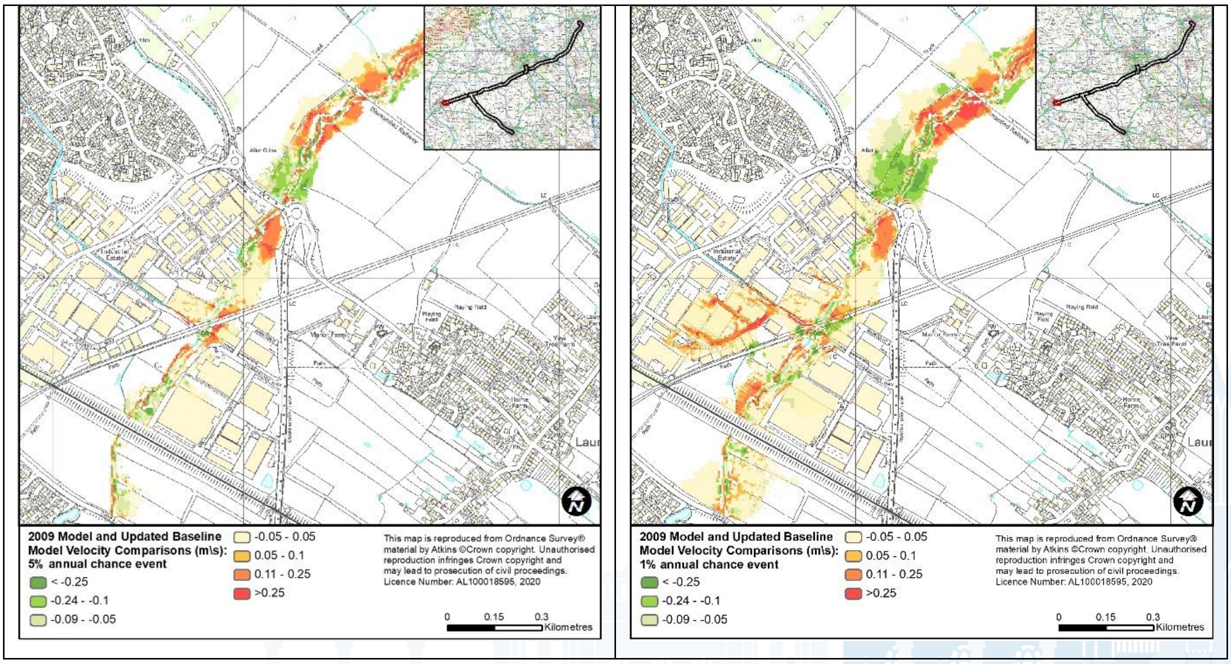


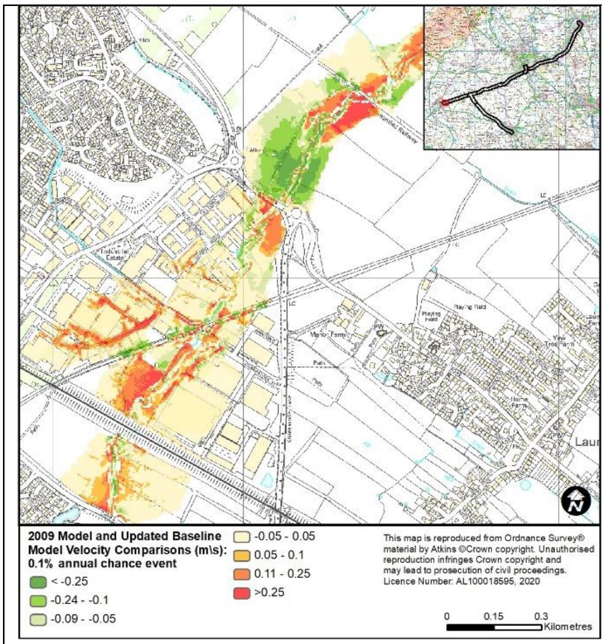
Figure 4-6 0.1% annual chance event comparisons



The following figures compare the 5% annual chance event, 1% annual chance event and 0.1% annual chance event velocities, which shows greater variation from the 2009 model in the more extreme events (1% and 0.1% annual chance events).

Figure 4-7 Velocity Comparisons





With Scheme (permanent)

With Scheme Model Representation

The updated 2020 baseline model was updated with the following changes:

- The CFSA adjacent the EWR2 route has been represented by adding the proposed CFSA DTM to the hydraulic model;
- The model DTM has been modified to include the proposed backwater channel located in the existing floodplain on the left bank of the Langford Brook, approximately 160m upstream of culvert C180814;
- The model DTM has been modified to include the proposed rail embankment works and highway overbridge at Charbridge Lane; and
- Culvert C180814 has been modelled with a reduced diameter to represent the liner proposal and a reduced mannings n roughness coefficient.

The CFSA was designed based upon the combined level area relationship described in Section 3 of the main report. The existing ground levels at the CFSA site were reviewed and the CFSA area defined at GRIP 4 used as a basis for the location, ensuring the CFSA falls outside of existing floodplains but connecting back into the floodplain area to allow flood water to flow from the watercourse freely into the CFSA, and back into the watercourse following the event. This will enable the CFSA to operate without the need for control structures.

Comparison of results

The following section compares the results of the updated 2020 baseline and With Scheme (permanent) scenario. The following figures compare the stage hydrographs for the 1% annual chance event, at the following locations:

1) Adjacent the proposed EWR2 CFSA (cross section LA.4560)

2) Upstream of the existing EWR2 embankment (cross section LA.4005)

3) Downstream of the existing EWR2 embankment (cross section LA.3858)

These figures show the changes in stage between the updated 2020 baseline model and the With Scheme (permanent) model.

Figure 4-8 Comparison of stage hydrographs at the EWR2 CFSA

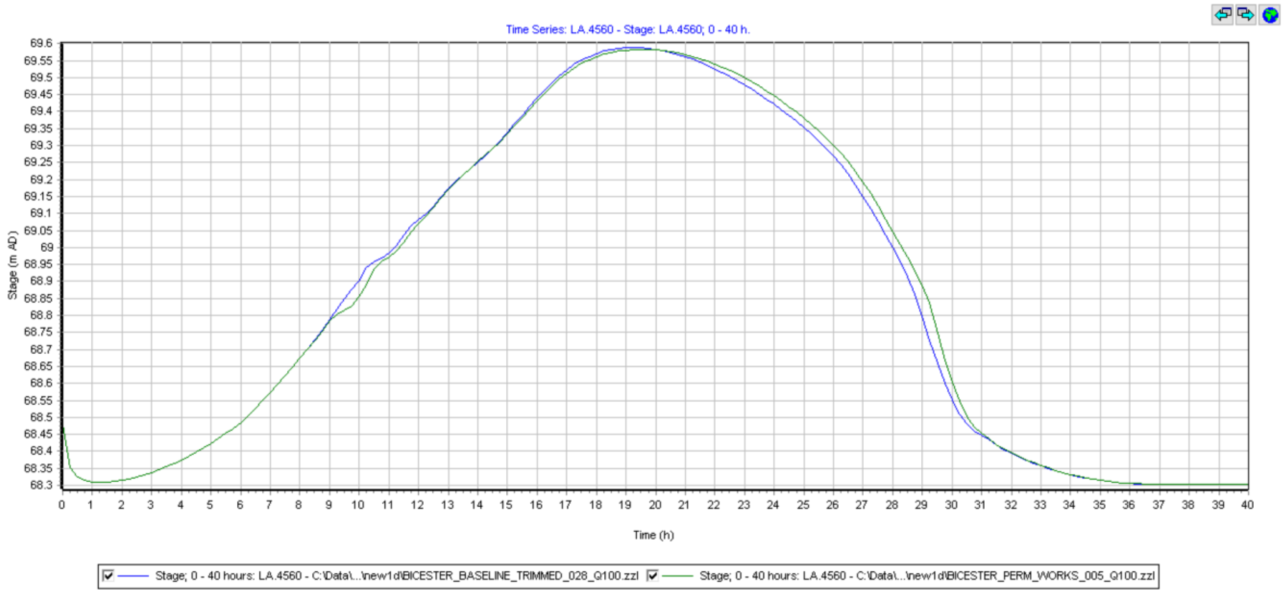


Figure 4-9 Comparison of stage hydrographs upstream of the EWR2 embankment

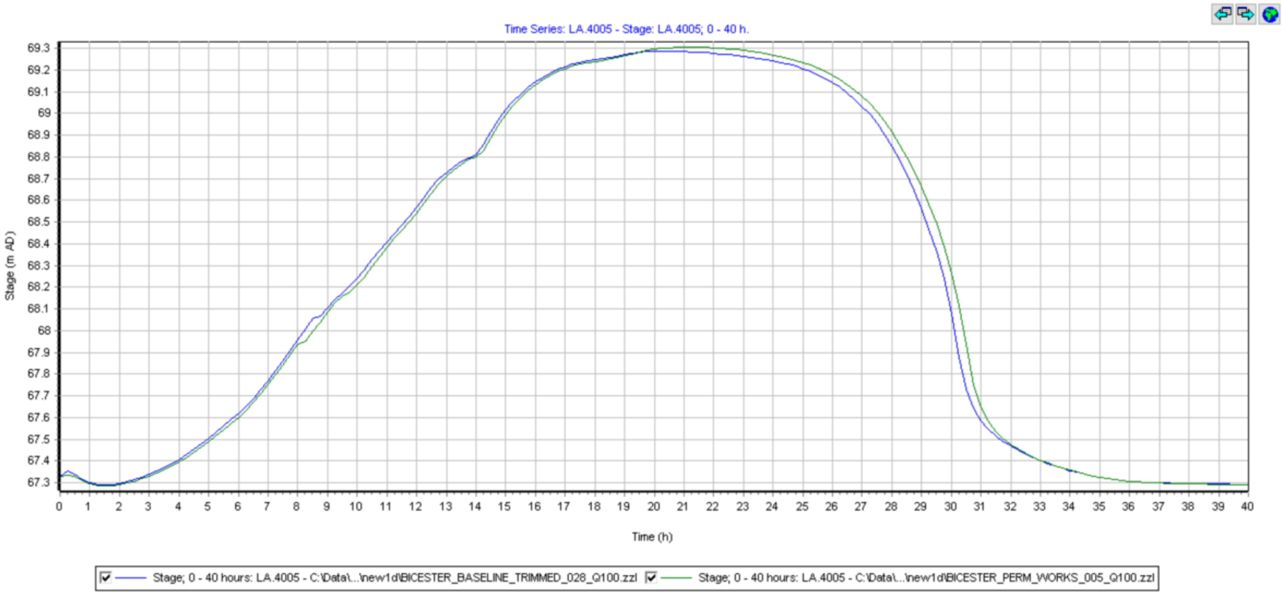
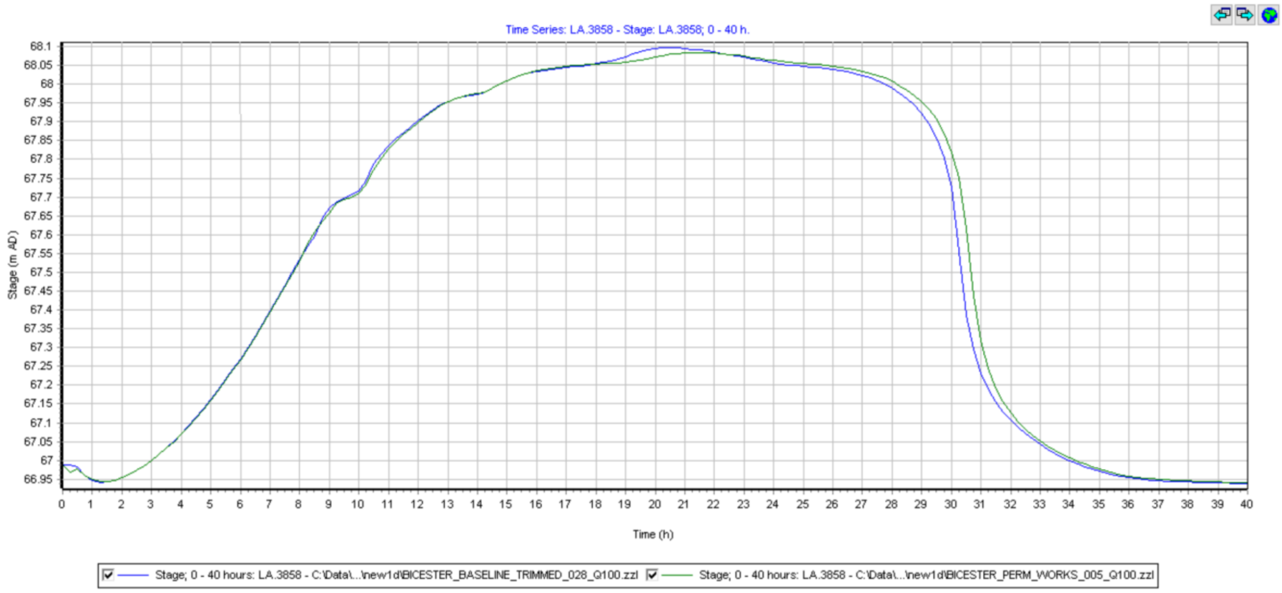


Figure 4-10 Comparison of stage hydrographs downstream of the EWR2 embankment



The following figures compare the 5% annual chance event, 1% annual chance event and 1% annual chance event plus climate change (70%) flood outlines and differences in flood levels. When comparing the figures below it can be observed that the differences shown between the 2009 baseline and 2020 baseline far exceed those shown between the 2020 baseline and the With scheme (permanent) results.

Figure 4-11 5% annual chance event comparisons

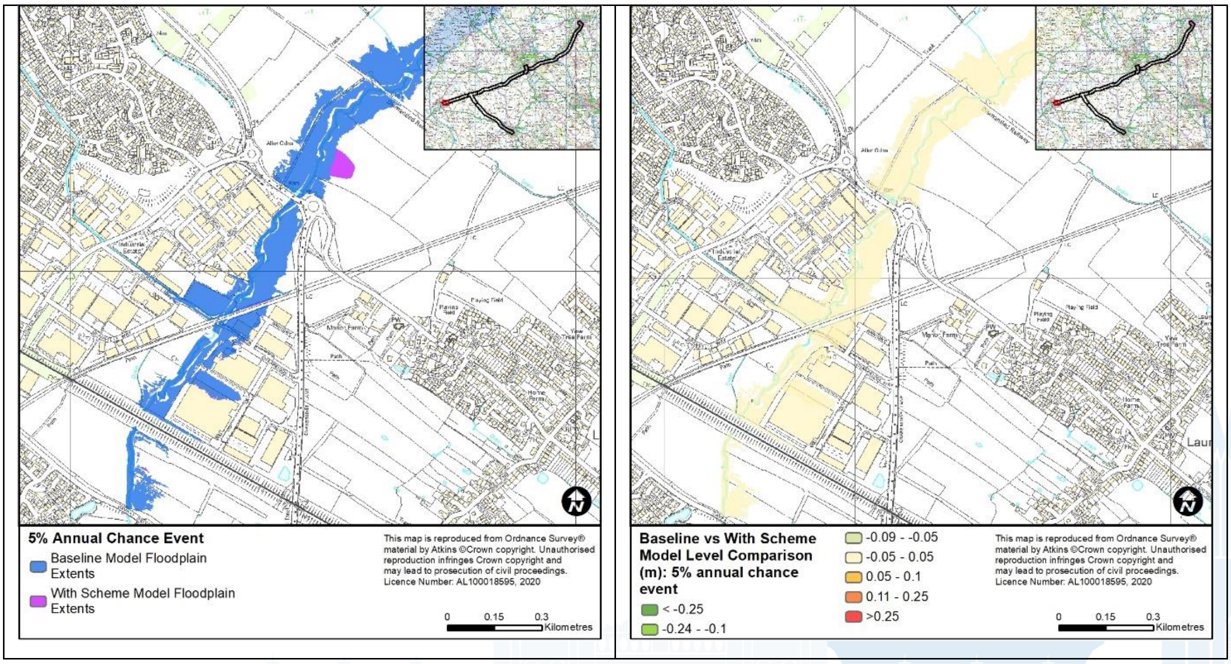


Figure 4-12 1% annual chance event comparisons

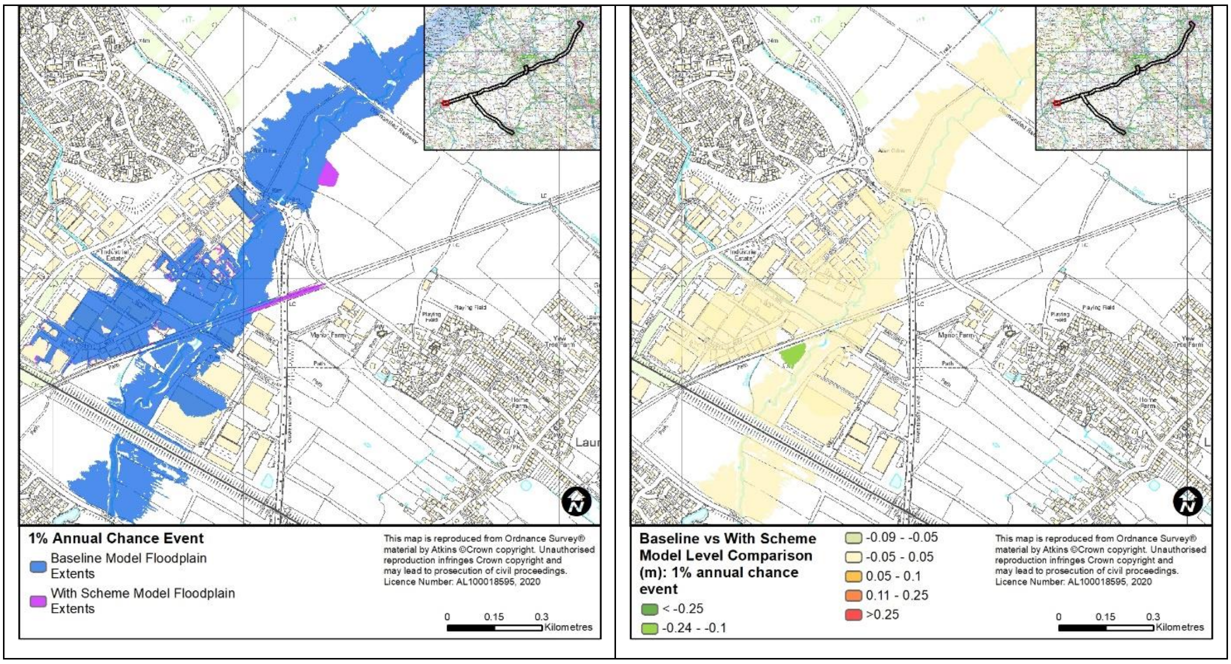
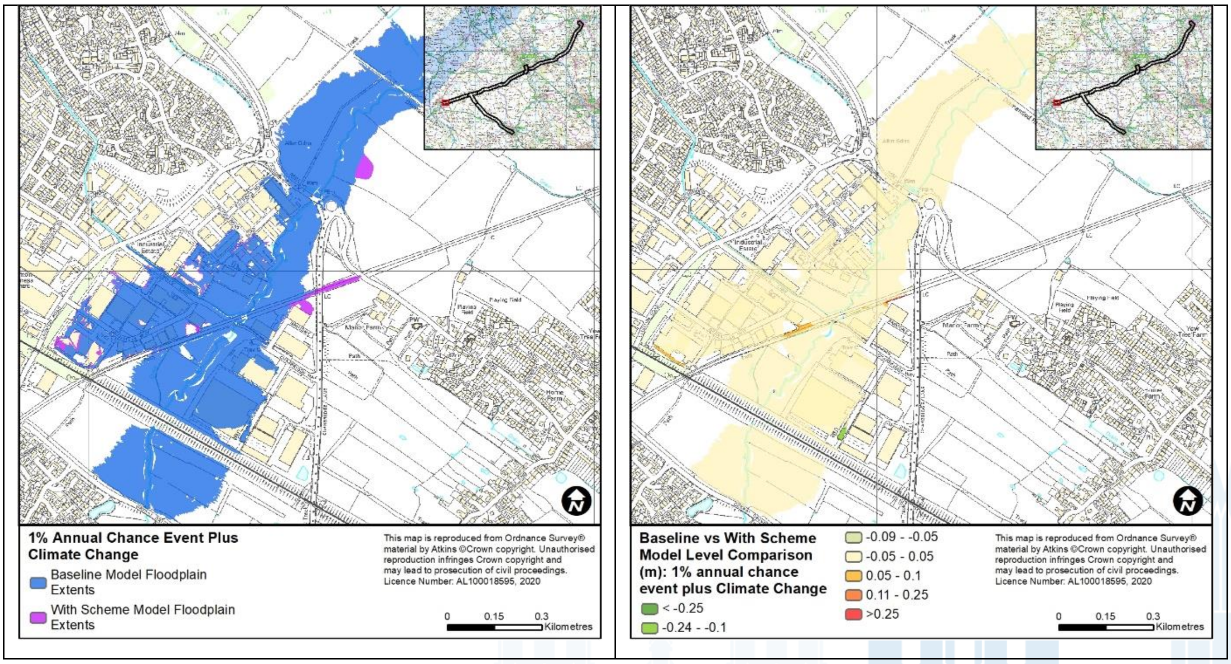
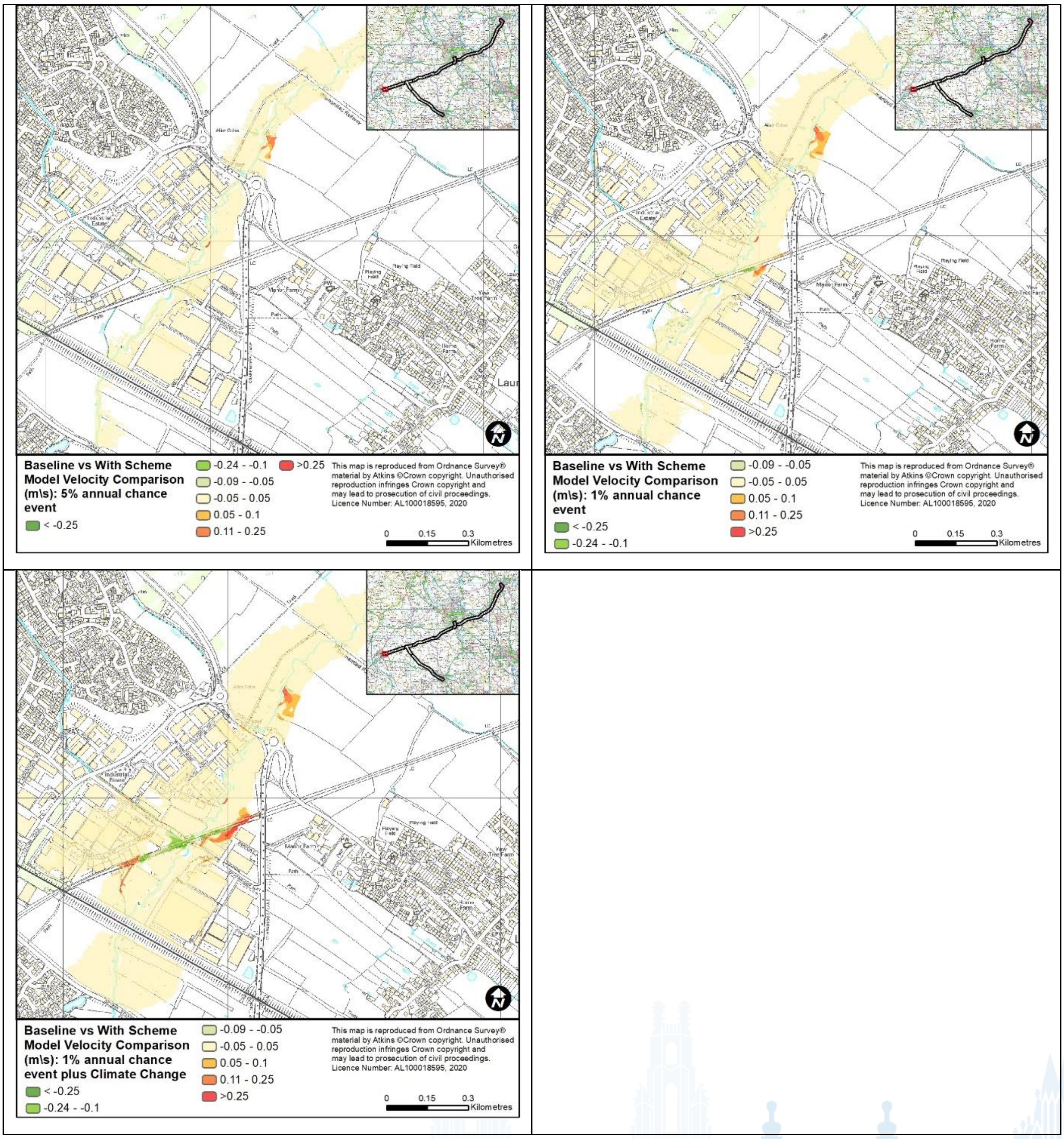


Figure 4-13 1% annual chance event plus climate change (70%) comparisons



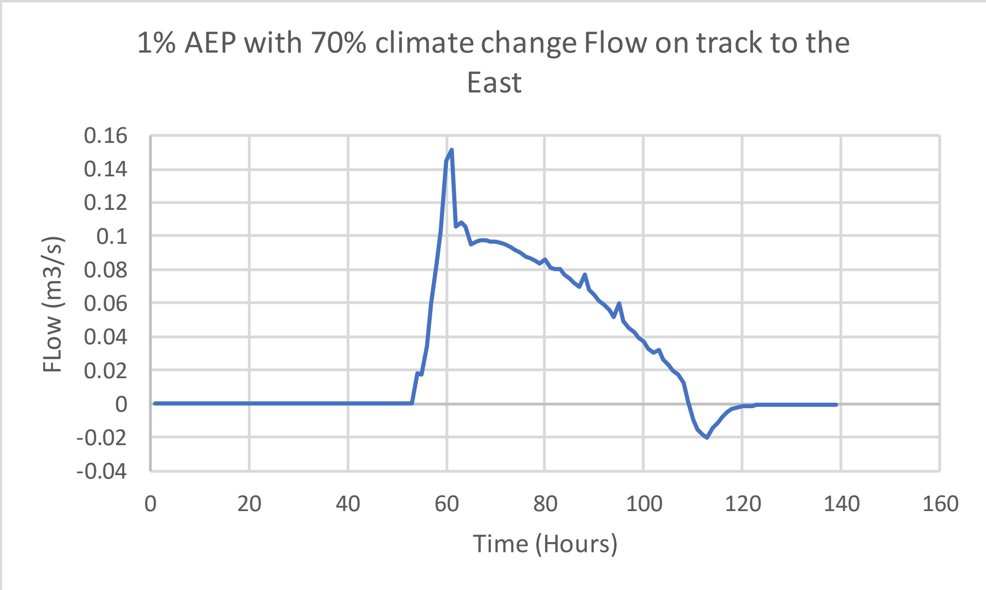
The following figures compare the 5% annual chance event, 1% annual chance event and 1% annual chance event plus climate change (70%) velocities, and, like the differences in extent and level shows less variation than between the 2009 baseline model and 2020 updated baseline model, with changes centred around the EWR2 embankment.

Figure 4-14 Velocity Comparisons



In the 1% annual chance event a flow path develops along the railway line, which flows to the east under Charbridge Lane overbridge. This new flow path is caused by the slight lowering of the EWR2 embankment in this area in order for the track to pass beneath the new overbridge which will replace the level crossing. By doing so a small volume of water in the floodplain from the north can flow onto the track during extreme flood events. Whilst not included in the hydraulic model, in reality the track drainage will manage these flows, with peak flows of 150 l/s predicted by the model along the track at the 1% annual chance plus 70% climate change flood event. This rapidly falls to below 100 l/s and is active only for 10 hours in the most extreme event.

Figure 4-15 Flow route hydrograph



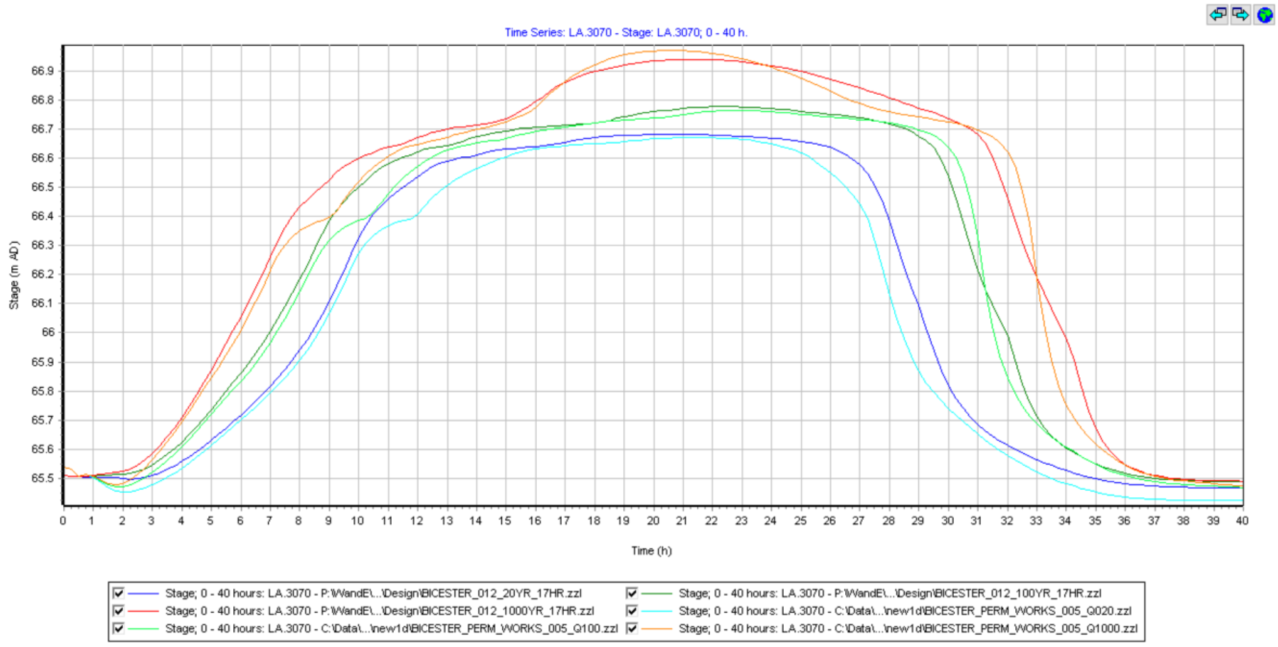
Flood Warning Gauge on Langford Brook

The proposed CFSA is unlikely to have a notable impact on the lag time of the catchment based on comparisons to the original 2009 model. A CFSA (Compensatory Flood Storage Area) is designed to operate as compensation for lost floodplain due to essential infrastructure works in the floodplain, as such the same amount of storage on a level for level basis is provided as that which is lost as close to the location of loss as practicably possible. The CFSA will make up a small percentage of the volume of the hydrograph and will provide betterment in the catchment.

The original model report included calibration of the model on the Langford Brook from a gauge located at model node LA.3070. This is located immediately downstream of Gavray Drive, no data is available elsewhere in the truncated model catchment or upstream of this location. The figures below compare the stage and flow hydrographs between the 2009 model and the With Scheme (permanent) model for the 5%, 1% and 0.1% annual chance events at the gauge location.

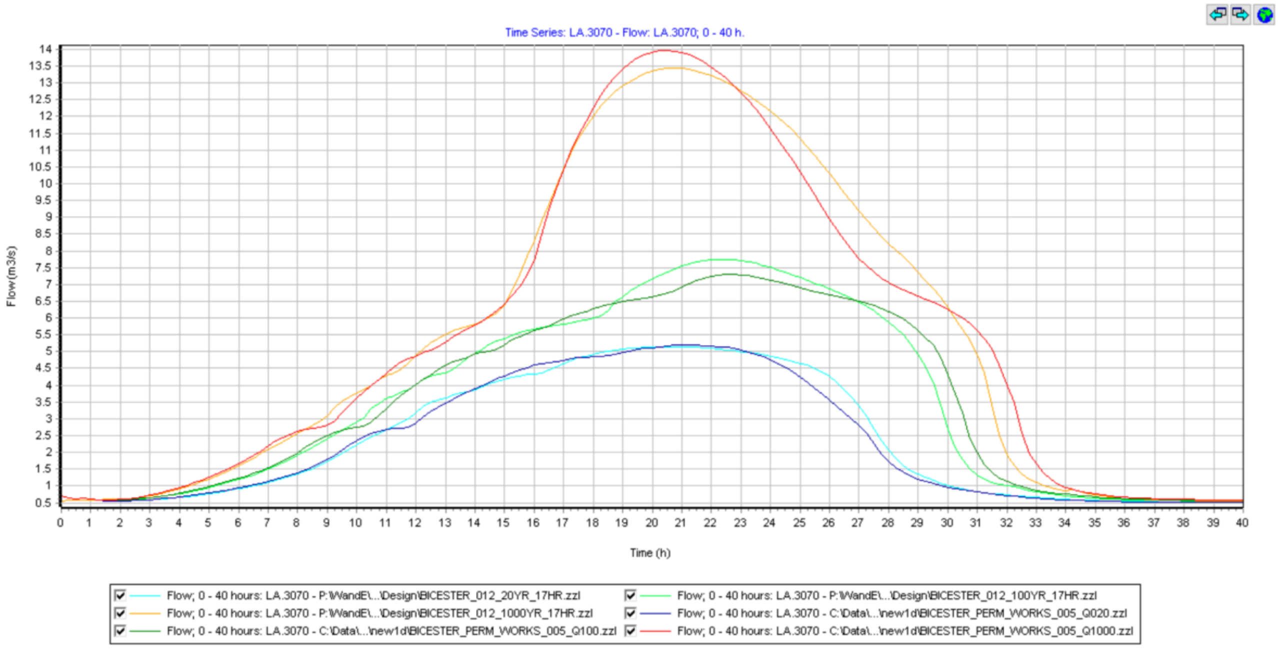
The timing and peaks are consistent, although the hydrographs are slightly narrower in the new model suggesting slightly less volume in the floodplain during the early event, this is in keeping with the improved cell resolution. Given the higher resolution of the updated model and large reduction in mass balance errors changes of this magnitude are expected as more detailed flow paths are now represented within the floodplain. The slight shift in timing is likely the result of the updated LiDAR in the EWR2 area, correction of mass balance errors and better representation of spills in terms of timing and volume, as the low spots are no longer in the model. This means the flood cells have slightly more storage than previous, which affects the hydrograph shape.

Figure 4-16 Stage hydrograph comparisons at Langford Brook gauge



The flow hydrographs below confirm that there is limited change in the flow hydrographs, both in terms of peak and timings.

Figure 4-17 Flow hydrograph comparisons at Langford Brook gauge



5. Summary

As with any model there are uncertainties present within the modelled reach, largely relating to topographic levels, changes in LiDAR and some minor localised Mass Balance issues in some 1D-2D links. These uncertainties have been investigated through use of sensitivity analysis to provide evidence that their potential impact will be negligible.

The updated 2020 model builds on the calibrated Environment Agency model of 2009 and applies the same hydrology to ensure a precautionary approach is adopted. In terms of the flood risk mechanisms and broad locations of the out of bank flows the updated 2020 model is consistent with the 2009 modelling, with extensive flooding predicted in some areas. The model has been improved with more recent topographical data, improved model resolution, reduced model instabilities and Mass Balance issues, and through extensive sensitivity testing demonstrated that where uncertainties exist these do not impact on model results.

As discussed with the Environment Agency on 7th and 16th July 2020 the updated model is therefore an improvement on the 2009 model. As a result, the updated 2020 model is suitable for the purposes of assessing the CFSA requirements for the EWR2 scheme.

This Appendix has documented the hydraulic model updates and checks made to the Langford Brook hydrological and hydraulic model in response to the Environment Agency review comments. The updates and responses were discussed and agreed with the Environment Agency during meetings on 7th and 16th July 2020.

Appendix G. CFSA Calculation Record

Appendix G: CFSA Calculation Record

This assessment has been undertaken to show the volume of floodplain losses due to the EWR2 scheme and size the proposed Compensatory Flood Storage Areas (CFSA). The following data was used in this assessment:

- Existing ground model;
- Proposed ground (including both temporary and permanent works) model; and
- Flood level grids from the Langford Brook hydraulic model.

General Layout

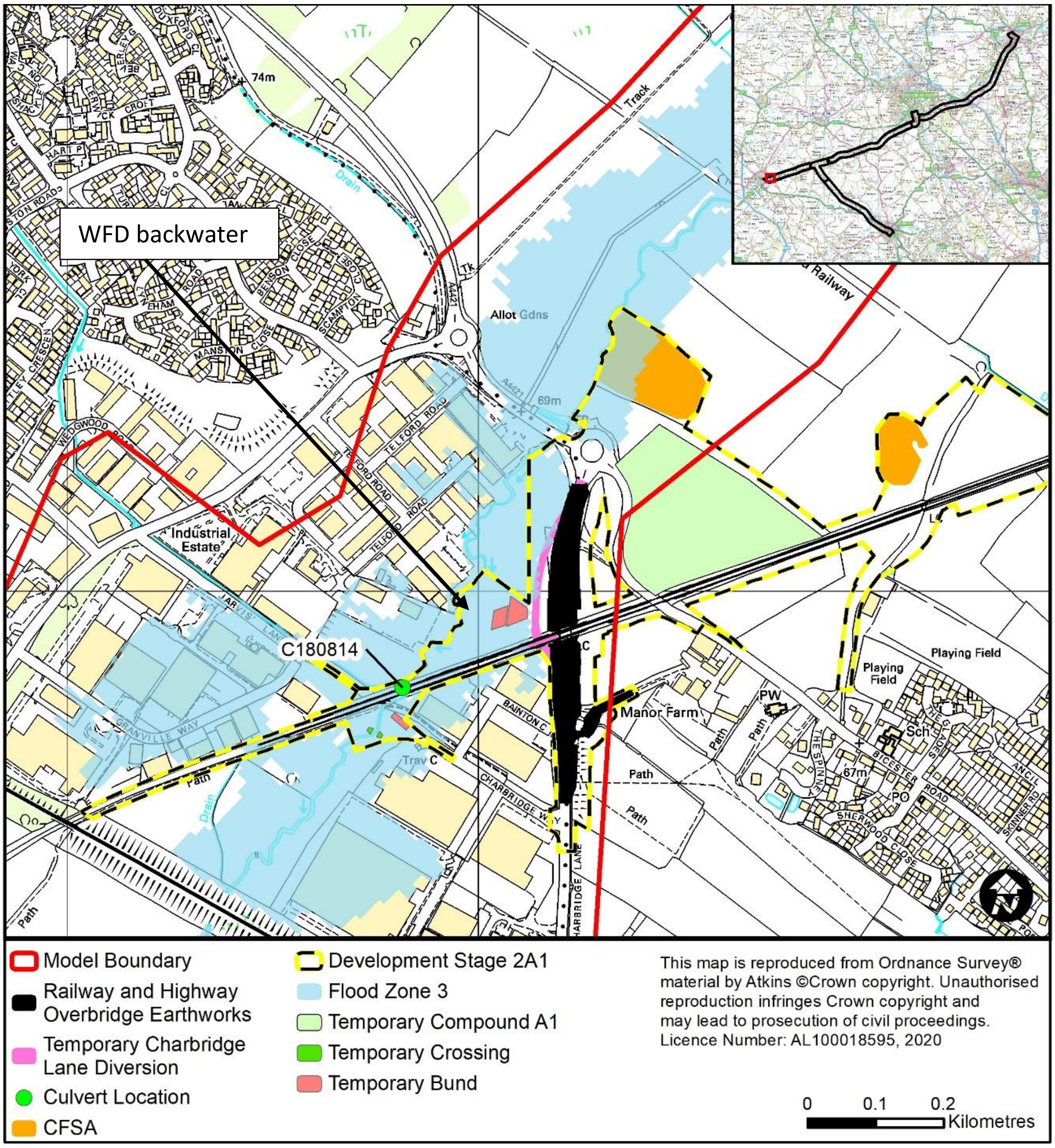
There are a number of elements of both the permanent works and the temporary works that are required to construct the permanent features. The phasing of the works and placement of materials have been designed to ensure that the combined volume of floodplain loss due to the temporary and permanent works combined is less than that provided by the CFSA. This has been provided on a level for level basis and all works including the temporary case compensated for up to a 1% annual chance event including 70% climate change allowance. This is therefore a precautionary approach.

The proposed works that are located within the floodplain of the Langford Brook are shown in the location plan below.

The temporary Charbridge Lane road diversion will be in place for 12-14 months. This will pass through floodplain areas and therefore compensation will be required. There are two aspects to the proposed works that will impact the floodplain of Langford Brook, these are shown in the location plan below, namely:

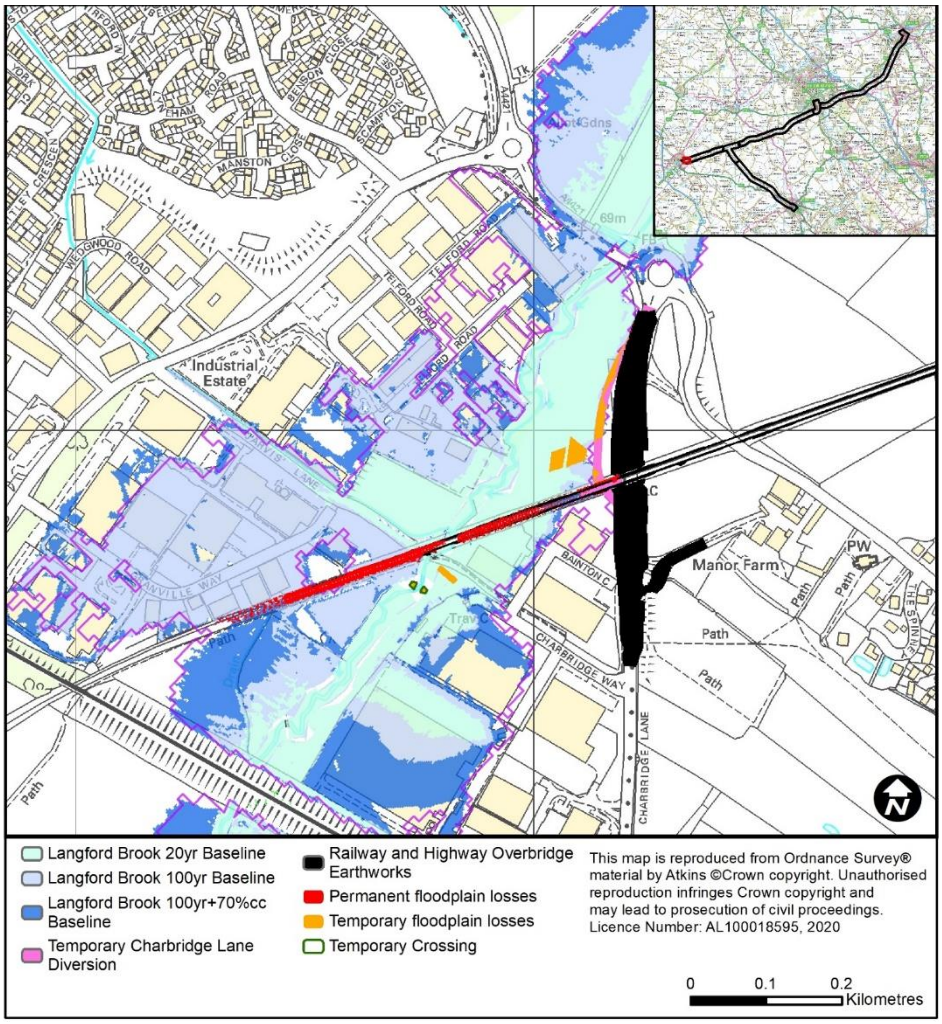
1. The temporary works required to divert the road during construction of the proposed new overbridge, temporary construction storage and haul road; and
2. The permanent works comprising the proposed railway embankment works, the proposed overbridge and the proposed backwater channel.

The WFD backwater lowers ground levels in the floodplain and therefore does not need to be accounted for in the assessment of floodplain losses. The layout of temporary Compound A1 has been adjusted to avoid floodplain areas and is now located entirely outside of the 1% annual chance event including climate change (70%) floodplain; therefore, no compensation is required for the Compound.



Floodplain Losses

Both the temporary and permanent elements have been assessed for floodplain volume losses separately with a combined CFSA proposed to compensate for the volume losses. The volume of floodplain lost during each flood event over-and-above the previous assessed event is listed in the fourth column in the tables below for each 0.2m increment.



Losses from permanent works:

Annual Chance Event	Total Volume lost (m³)	Flood level at gain site (mAOD)	Volume lost at Increment (m³)
20%	25	69.17	25
5%	27	69.28	3
2%	63	69.45	36
1%	195	69.59	132
1% + 70% climate change	270	69.77	75

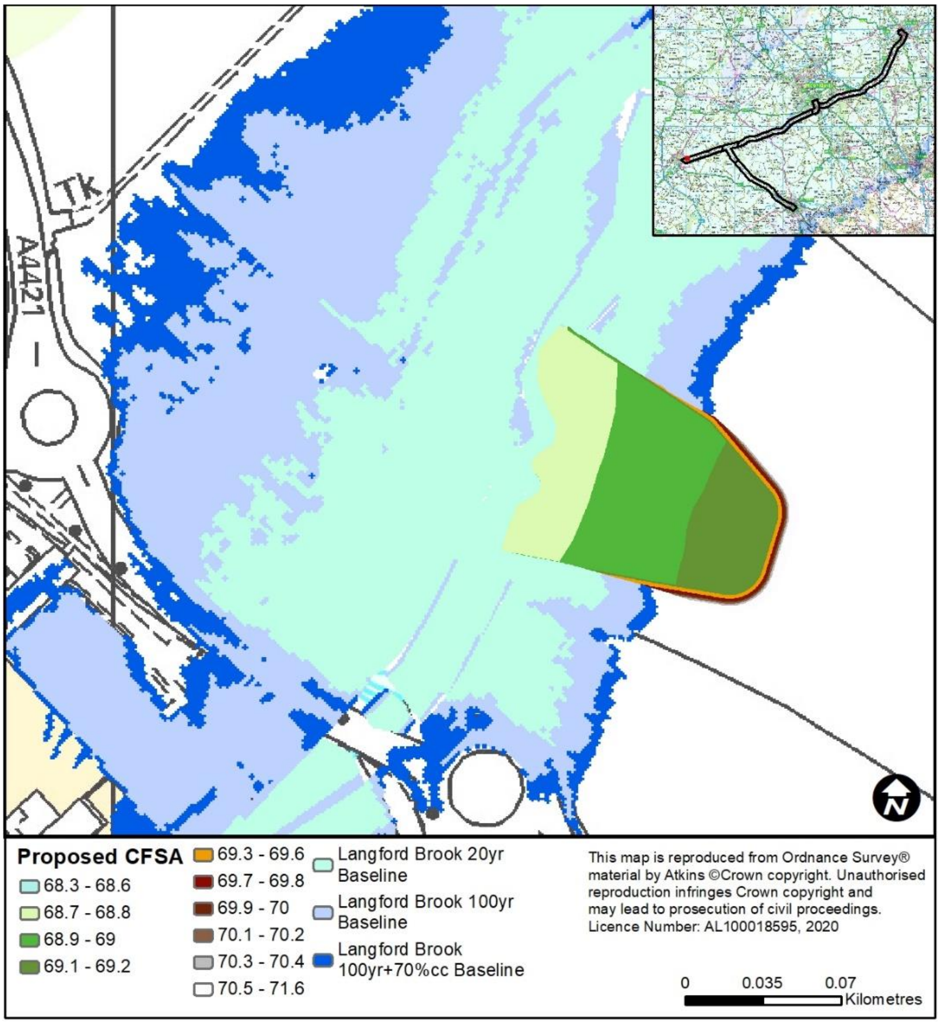
Losses from temporary works and permanent works:

Flood Event	Total Volume lost (m³)	Flood level at gain site (mAOD)	Volume lost at Increment (m³)
20%	137	69.17	137
5%	460	69.28	323
2%	881	69.45	421
1%	1195	69.59	314
1% + 70% climate change	1450	69.77	255

CFSA

The differences in peak flood levels shown above are too small to construct a viable CFSA at such a fine scale, therefore the total losses have been condensed into a single 0.2m band deemed the minimum feasible for construction, shown below.

Proposed CFSA:



CFSA gains for temporary and permanent works

The CFSA provides a total storage volume of 2287m³ giving an overprovision in storage for all level bands. This storage will remain in place when the temporary works are removed providing permanent additional floodplain storage for the catchment >2000m³, and an overprovision during the temporary and permanent scenario of >800m³.

Increment (at/up to level) based on loss level (mAOD)	Total Volume lost (temporary and permanent) at increment (m^3)	Volume Gained at increment (m^3)	Overprovision (temporary and permanent) (m^3)	Overprovision (permanent) (m^3)
69.17	137	440	303	415
69.37	323	595	272	592
69.57	421	617	196	581
69.77	569	635	66	428
Total (m^3)	**1450**	**2287**	**837**	**2017**

Appendix H. Baseline Model Results

	Baseline Peak Water Level (mAOD)					
Node	**20% annual chance event**	**5% annual chance event**	**2% annual chance event**	**1% annual chance event**	**1% plus climate change (70%) annual chance event**	**0.1% annual chance event**
LA.1.6715_IN	72.60	72.81	72.93	72.99	73.16	73.14
LA.1.6715_BF	72.60	72.81	72.93	72.99	73.16	73.14
LA.2_IN	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
LA.3_IN	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
LA.6715	72.60	72.81	72.93	72.99	73.16	73.14
LA.6482	72.17	72.33	72.37	72.39	72.42	72.42
LA.6239	71.69	71.77	71.78	71.79	71.83	71.82
LA.5966	71.16	71.23	71.27	71.30	71.39	71.38
LA.5734	70.72	70.77	70.81	70.83	70.91	70.90
LA.5527	70.50	70.53	70.56	70.57	70.63	70.63
LA.5527BU	70.50	70.53	70.56	70.57	70.63	70.63
LA.5522BD	70.40	70.45	70.48	70.50	70.57	70.56
LA.5527SU	70.50	70.53	70.56	70.57	70.63	70.63
LA.5522SD	70.40	70.45	70.48	70.50	70.57	70.56
LA.5522	70.40	70.45	70.48	70.50	70.57	70.56
LA.5462i	70.34	70.40	70.43	70.45	70.52	70.51
LA.5412i	70.26	70.33	70.36	70.38	70.46	70.45
LA.5362i	70.19	70.27	70.31	70.33	70.40	70.39
LA.5312i	70.11	70.19	70.23	70.25	70.33	70.32
LA.5262i	70.02	70.11	70.15	70.17	70.27	70.26
LA.5212i	69.94	70.03	70.07	70.09	70.23	70.22
LA.5162i	69.88	69.97	70.02	70.05	70.22	70.20
LA.5112i	69.84	69.92	69.98	70.02	70.21	70.19
LA.5112	69.83	69.92	69.98	70.02	70.21	70.19
LA.5112_O1U	69.83	69.92	69.98	70.02	70.21	70.19
LA.5107_O1D	69.78	69.90	69.97	70.02	70.21	70.19
LA.5112_O2U	69.83	69.92	69.98	70.02	70.21	70.19
LA.5107_O2D	69.78	69.90	69.97	70.02	70.21	70.19
LA.5112_O3U	69.83	69.92	69.98	70.02	70.21	70.19
LA.5107_O3D	69.78	69.90	69.97	70.02	70.21	70.19
LA.5112SU	69.83	69.92	69.98	70.02	70.21	70.19
LA.5107SD	69.78	69.90	69.97	70.02	70.21	70.19
LA.5098	69.78	69.90	69.97	70.02	70.21	70.19
LA.5098i	69.76	69.90	69.97	70.01	70.21	70.19
LA.4998i	69.71	69.87	69.95	69.99	70.19	70.17
LA.5048i	69.75	69.89	69.96	70.01	70.20	70.18
LA.4998	69.67	69.81	69.86	69.90	70.07	70.06
LA.4998SU	69.67	69.81	69.86	69.90	70.07	70.06
LA.4998SD	69.66	69.79	69.82	69.84	69.91	69.90
LA.4998BU	69.67	69.81	69.86	69.90	70.07	70.06
LA.4998BD	69.66	69.79	69.82	69.84	69.91	69.90
LA.4998D	69.66	69.79	69.82	69.84	69.91	69.90
LA.4998Di	69.61	69.74	69.76	69.77	69.84	69.83
LA.4948i	69.56	69.70	69.73	69.74	69.82	69.82
LA.4898i	69.46	69.61	69.65	69.69	69.80	69.79
LA.4898i2	69.41	69.55	69.58	69.65	69.79	69.78
LA.4848i	69.38	69.50	69.54	69.62	69.78	69.77
LA.4798i	69.31	69.42	69.49	69.60	69.77	69.77
LA.4748	69.24	69.33	69.46	69.59	69.77	69.76
LA.4663	69.12	69.24	69.45	69.59	69.77	69.76
LA.4560	69.03	69.21	69.44	69.59	69.76	69.76
LA.4560In1	69.02	69.20	69.44	69.59	69.76	69.75
LA.4560In2	69.01	69.20	69.44	69.59	69.76	69.75
LA.4560In3	68.98	69.18	69.44	69.58	69.76	69.75
LA.4493	68.95	69.14	69.42	69.57	69.75	69.75
LA.4493SU	68.95	69.14	69.42	69.57	69.75	69.75
LA.4493SD	68.87	69.10	69.41	69.56	69.75	69.74
LA.4493BU	68.95	69.14	69.42	69.57	69.75	69.75
LA.4493BD	68.87	69.10	69.41	69.56	69.75	69.74
LA.4493D	68.87	69.10	69.41	69.56	69.75	69.74
LA.4474	68.82	69.00	69.33	69.49	69.68	69.67
LA.4474BU	68.82	69.00	69.33	69.49	69.68	69.67
LA.4462BD	68.77	68.89	69.20	69.30	69.39	69.39
LA.4474SU	68.82	69.00	69.33	69.49	69.68	69.67
LA.4462SD	68.77	68.89	69.20	69.30	69.39	69.39
LA.4458	68.77	68.89	69.20	69.30	69.39	69.39
LA.4323	68.57	68.84	69.18	69.29	69.37	69.37
LA.4157	68.37	68.83	69.18	69.29	69.37	69.37

	Baseline Peak Water Level (mAOD)					
Node	20% annual chance event	5% annual chance event	2% annual chance event	1% annual chance event	1% plus climate change (70%) annual chance event	0.1% annual chance event
LA.4005	68.32	68.83	69.18	69.29	69.37	69.36
LA.3919	68.27	68.80	69.16	69.27	69.36	69.36
LA.3905	68.25	68.79	69.15	69.27	69.35	69.35
LA.3905_IN	68.25	68.79	69.15	69.27	69.35	69.35
LA.3905CU	68.19	68.63	68.92	69.03	69.14	69.13
LA.3894CD	68.05	68.30	68.44	68.52	68.70	68.69
LA.3894_OUT	68.00	68.13	68.17	68.21	68.37	68.36
LA.3905SU	68.25	68.79	69.15	69.27	69.35	69.35
LA.3894SD	68.00	68.13	68.17	68.21	68.37	68.36
LA.3894	68.00	68.13	68.17	68.21	68.37	68.36
LA.3876	67.98	68.13	68.18	68.23	68.39	68.37
LA.3865	67.97	68.12	68.18	68.23	68.39	68.37
LA.3865BU	67.97	68.12	68.18	68.23	68.39	68.37
LA.3858BD	67.80	67.98	68.04	68.10	68.30	68.27
LA.3865SU	67.97	68.12	68.18	68.23	68.39	68.37
LA.3858SD	67.80	67.98	68.04	68.10	68.30	68.27
LA.3858	67.80	67.98	68.04	68.10	68.30	68.27
LA.3764	67.60	67.77	67.83	67.89	68.21	68.16
LA.3597	67.21	67.46	67.52	67.57	68.16	68.10
LA.3503	67.00	67.30	67.40	67.51	68.16	68.10
LA.3503BU	67.00	67.30	67.40	67.51	68.16	68.10
LA.3500_RBD	67.00	67.25	67.36	67.50	68.16	68.11
LA.3503SU	67.00	67.30	67.40	67.51	68.16	68.10
LA.3500_RSD	67.00	67.25	67.36	67.50	68.16	68.11
LA.3500_R	67.00	67.25	67.36	67.50	68.16	68.11
LA.3439	66.93	67.20	67.32	67.46	68.15	68.09
LA.3428	66.92	67.19	67.31	67.45	68.13	68.07
LA.3428_IN	66.92	67.19	67.31	67.45	68.13	68.07
LA.3428CU	66.89	67.15	67.26	67.38	68.00	67.95
LA.3372CD	66.80	67.01	67.08	67.13	67.44	67.40
LA.3372X1	66.80	67.01	67.08	67.13	67.44	67.40
LA.3372X2	66.81	67.02	67.09	67.15	67.48	67.44
LA.3372_OUT	66.78	66.97	67.02	67.05	67.23	67.20
LA.3372	66.78	66.97	67.02	67.05	67.23	67.20
LA.3352	66.77	66.98	67.05	67.11	67.29	67.27
LA.3272	66.69	66.89	66.95	66.99	67.22	67.20
LA.3178	66.60	66.78	66.85	66.91	67.21	67.19
LA.3109	66.51	66.69	66.76	66.83	67.16	67.14
LA.3088	66.51	66.69	66.75	66.83	67.14	67.11
LA.3088_IN	66.51	66.69	66.75	66.83	67.14	67.11
LA.3088CU	66.51	66.68	66.74	66.81	67.09	67.07
LA.3070CD	66.51	66.68	66.74	66.80	67.07	67.05
LA.3070_OUT	66.50	66.67	66.73	66.78	66.99	66.97
LA.3088_O1U	66.51	66.69	66.75	66.83	67.14	67.11
LA.3070_O1D	66.50	66.67	66.73	66.78	66.99	66.97
LA.3088_O2U	66.51	66.69	66.75	66.83	67.14	67.11
LA.3070_O2D	66.50	66.67	66.73	66.78	66.99	66.97
LA.3088_O3U	66.51	66.69	66.75	66.83	67.14	67.11
LA.3070_O3D	66.50	66.67	66.73	66.78	66.99	66.97
LA.3088SU	66.51	66.69	66.75	66.83	67.14	67.11
LA.3070SD	66.50	66.67	66.73	66.78	66.99	66.97
LA.3070	66.50	66.67	66.73	66.78	66.99	66.97
LA.3057	66.50	66.66	66.72	66.77	66.97	66.95
LA.2933	66.40	66.55	66.61	66.66	66.84	66.83
LA.2832	66.33	66.48	66.53	66.59	66.78	66.76
LA.2733	66.27	66.43	66.48	66.54	66.73	66.71
LA.3919_L	68.27	68.80	69.16	69.27	69.36	69.36
LA.4493D_L	68.87	69.10	69.41	69.56	69.75	69.74
LA.5098_L	69.78	69.90	69.97	70.02	70.21	70.19
LA.5966_L	71.16	71.23	71.27	71.30	71.39	71.38
LA.3858In1	67.74	67.91	67.98	68.04	68.26	68.23
LA.3808A	67.70	67.87	67.95	68.01	68.25	68.21
LA.3808B	67.70	67.87	67.95	68.01	68.25	68.21
LA.3858In2	67.67	67.84	67.91	67.97	68.24	68.19

	Baseline Peak Flow (m^3/s)					
Node	20% annual chance event	5% annual chance event	2% annual chance event	1% annual chance event	1% plus climate change (70%) annual chance event	0.1% annual chance event
LA.1.6715_IN	2.33	4.20	5.80	6.82	11.59	10.92
LA.1.6715_BF	0.40	0.40	0.40	0.40	0.40	0.40
LA.2_IN	0.44	0.88	1.28	1.55	2.64	2.78
LA.3_IN	0.88	1.59	2.19	2.57	4.37	4.10
LA.6715	2.73	4.60	6.20	7.22	11.99	11.32
LA.6482	2.73	4.25	5.20	5.70	6.57	6.57
LA.6239	2.73	3.55	3.69	3.70	3.84	3.79
LA.5966	2.38	2.58	2.68	2.77	3.10	3.06
LA.5734	2.56	3.12	3.61	3.88	5.02	4.88
LA.5527	1.47	1.48	1.49	1.57	1.98	1.93
LA.5527BU	1.45	1.46	1.46	1.46	1.46	1.46
LA.5522BD	1.45	1.46	1.46	1.46	1.46	1.46
LA.5527SU	0.11	0.24	0.40	0.51	1.00	0.94
LA.5522SD	0.11	0.24	0.40	0.51	1.00	0.94
LA.5522	1.47	1.48	1.49	1.57	1.98	1.93
LA.5462i	1.64	1.93	2.19	2.33	2.89	2.82
LA.5412i	2.07	2.44	2.69	2.85	3.54	3.45
LA.5362i	2.14	2.60	2.86	3.03	3.66	3.60
LA.5312i	2.51	3.33	3.78	4.05	5.01	4.87
LA.5262i	2.52	3.36	3.81	4.09	4.80	4.73
LA.5212i	2.48	3.54	4.10	4.37	4.82	4.75
LA.5162i	2.51	3.34	3.56	3.60	3.67	3.63
LA.5112i	2.62	4.00	4.46	4.50	4.58	4.52
LA.5112	1.93	2.22	2.23	2.23	2.25	2.21
LA.5112_O1U	0.52	0.52	0.52	0.52	0.52	0.52
LA.5107_O1D	0.52	0.52	0.52	0.52	0.52	0.52
LA.5112_O2U	0.52	0.52	0.52	0.52	0.52	0.52
LA.5107_O2D	0.52	0.52	0.52	0.52	0.52	0.52
LA.5112_O3U	0.31	0.30	0.30	0.30	0.30	0.29
LA.5107_O3D	0.31	0.30	0.30	0.30	0.30	0.29
LA.5112SU	1.40	1.93	1.93	1.93	1.96	1.92
LA.5107SD	1.40	1.93	1.93	1.93	1.96	1.92
LA.5098	1.93	2.22	2.23	2.23	2.25	2.21
LA.5098i	2.31	2.41	2.45	2.46	2.61	2.59
LA.4998i	2.63	2.96	3.47	3.81	5.43	5.27
LA.5048i	2.59	2.71	2.76	2.78	2.80	2.81
LA.4998	3.02	5.25	7.09	8.31	13.74	13.21
LA.4998SU	0.00	0.00	0.00	0.00	0.02	0.01
LA.4998SD	0.00	0.00	0.00	0.00	0.02	0.01
LA.4998BU	3.02	5.25	7.09	8.31	13.73	13.20
LA.4998BD	3.02	5.25	7.09	8.31	13.73	13.20
LA.4998D	3.02	5.25	7.09	8.31	13.74	13.21
LA.4998Di	3.02	4.65	5.64	6.26	8.60	8.38
LA.4948i	3.02	4.11	4.29	4.31	4.98	4.89
LA.4898i	3.02	4.21	4.45	4.50	4.61	4.60
LA.4898i2	3.02	4.64	5.15	5.32	5.57	5.56
LA.4848i	3.02	4.64	5.17	5.36	5.64	5.63
LA.4798i	3.02	4.10	4.16	4.16	4.27	4.26
LA.4748	3.02	4.30	4.64	4.72	4.93	4.91
LA.4663	2.93	3.53	3.61	3.64	3.71	3.70
LA.4560	2.42	2.40	2.40	2.40	2.39	2.39
LA.4560In1	2.43	2.40	2.40	2.40	2.39	2.39
LA.4560In2	2.40	2.40	2.41	2.39	2.39	2.38
LA.4560In3	2.56	3.75	4.08	4.09	4.11	4.11
LA.4493	2.98	5.20	5.93	6.13	6.08	6.09
LA.4493SU	0.66	3.42	4.85	5.29	5.33	5.31
LA.4493SD	0.66	3.42	4.85	5.29	5.33	5.31
LA.4493BU	2.55	2.45	2.44	2.43	2.41	2.40
LA.4493BD	2.55	2.45	2.44	2.43	2.41	2.40
LA.4493D	2.98	5.20	5.93	6.13	6.08	6.09
LA.4474	3.06	5.38	6.74	7.92	9.17	9.12
LA.4474BU	3.06	5.38	6.74	7.92	9.17	9.12
LA.4462BD	3.06	5.38	6.74	7.92	9.17	9.12
LA.4474SU	0.00	0.00	0.00	0.00	0.00	0.00
LA.4462SD	0.00	0.00	0.00	0.00	0.00	0.00
LA.4458	3.06	5.38	6.74	7.92	9.17	9.12
LA.4323	3.04	3.14	3.02	2.98	2.90	2.92

	Baseline Peak Flow (m³/s)					
Node	20% annual chance event	5% annual chance event	2% annual chance event	1% annual chance event	1% plus climate change (70%) annual chance event	0.1% annual chance event
LA.4157	2.73	2.40	2.59	3.40	3.70	3.69
LA.4005	2.46	2.25	1.94	1.86	1.97	1.98
LA.3919	3.07	4.98	6.09	6.38	6.31	6.35
LA.3905	3.36	5.29	6.38	6.57	6.60	6.59
LA.3905_IN	3.36	5.29	6.38	6.57	6.60	6.59
LA.3905CU	3.36	5.29	6.38	6.57	6.60	6.59
LA.3894CD	3.36	5.29	6.38	6.57	6.60	6.59
LA.3894_OUT	3.36	5.29	6.38	6.57	6.60	6.59
LA.3905SU	0.00	0.00	0.00	0.00	0.31	0.28
LA.3894SD	0.00	0.00	0.00	0.00	0.31	0.28
LA.3894	3.36	5.29	6.38	6.57	6.60	6.59
LA.3876	2.91	3.18	3.44	3.59	4.36	4.32
LA.3865	2.91	3.00	3.02	3.02	3.49	3.45
LA.3865BU	2.91	3.00	3.02	3.02	3.02	3.03
LA.3858BD	2.91	3.00	3.02	3.02	3.02	3.03
LA.3865SU	0.00	0.14	0.27	0.42	1.16	1.07
LA.3858SD	0.00	0.14	0.27	0.42	1.16	1.07
LA.3858	2.91	3.00	3.02	3.02	3.49	3.45
LA.3764	3.35	4.96	5.61	6.45	9.54	9.41
LA.3597	3.35	4.87	5.74	6.53	6.97	6.95
LA.3503	3.35	4.85	4.86	4.89	4.95	4.95
LA.3503BU	3.35	4.85	4.86	4.89	4.95	4.95
LA.3500_RBD	3.35	4.85	4.86	4.89	4.95	4.95
LA.3503SU	0.00	0.00	0.05	0.29	0.49	0.48
LA.3500_RSD	0.00	0.00	0.05	0.29	0.49	0.48
LA.3500_R	3.35	4.85	4.86	4.89	4.95	4.95
LA.3439	3.34	5.04	5.87	6.87	9.28	9.17
LA.3428	3.34	5.18	6.36	7.88	14.92	14.33
LA.3428_IN	3.34	5.18	6.36	7.88	14.92	14.33
LA.3428CU	3.34	5.18	6.36	7.88	14.92	14.33
LA.3372CD	3.34	5.18	6.36	7.88	14.92	14.33
LA.3372X1	3.34	5.18	6.36	7.88	14.92	14.33
LA.3372X2	3.34	5.18	6.36	7.88	14.92	14.33
LA.3372_OUT	3.34	5.18	6.36	7.88	14.92	14.33
LA.3372	3.34	5.18	6.36	7.88	14.92	14.33
LA.3352	3.34	5.18	6.26	7.65	14.06	13.59
LA.3272	3.34	5.17	6.16	7.25	9.67	9.61
LA.3178	3.34	5.15	5.59	5.70	5.95	5.94
LA.3109	3.34	5.08	5.77	6.48	8.84	8.71
LA.3088	3.34	5.16	6.33	7.76	14.67	14.09
LA.3088_IN	3.05	4.30	5.12	6.28	11.92	11.45
LA.3088CU	3.05	4.30	5.12	6.28	11.92	11.45
LA.3070CD	3.05	4.30	5.12	6.28	11.92	11.45
LA.3070_OUT	3.05	4.30	5.12	6.28	11.92	11.45
LA.3088_O1U	0.09	0.31	0.35	0.43	0.80	0.77
LA.3070_O1D	0.09	0.31	0.35	0.43	0.80	0.77
LA.3088_O2U	0.10	0.36	0.43	0.52	0.97	0.94
LA.3070_O2D	0.10	0.36	0.43	0.52	0.97	0.94
LA.3088_O3U	0.10	0.23	0.43	0.52	0.97	0.94
LA.3070_O3D	0.10	0.23	0.43	0.52	0.97	0.94
LA.3088SU	0.00	0.00	0.00	0.00	0.00	0.00
LA.3070SD	0.00	0.00	0.00	0.00	0.00	0.00
LA.3070	3.34	5.16	6.33	7.76	14.67	14.09
LA.3057	3.34	5.16	6.33	7.76	14.67	14.09
LA.2933	3.34	5.16	6.33	7.75	14.66	14.08
LA.2832	3.34	5.16	6.32	7.75	14.66	14.08
LA.2733	3.33	5.16	6.32	7.75	14.66	14.08
LA.3919_L	0.88	1.59	2.19	2.57	4.37	4.10
LA.4493D_L	0.09	0.18	0.26	0.31	0.53	0.56
LA.5098_L	0.31	0.62	0.90	1.09	1.85	1.94
LA.5966_L	0.04	0.09	0.13	0.16	0.26	0.28
LA.3858In1	3.20	4.61	5.27	5.92	8.51	8.39
LA.3808A	3.34	5.09	5.85	6.75	9.96	9.80
LA.3808B	3.34	5.09	5.85	6.75	9.96	9.80
LA.3858In2	3.35	5.12	5.88	6.84	9.89	9.74

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