1D and 1D-2D Model Audit Report

JACOBS

Project	NATIONAL MODELLING AND FORECASTING TECHNICAL SUPPORT CONTRACT 2018-19: Hydrodynamic model of Ickenham Stream and River Pinn at Ruislip Golf Course, Ickenham to understand the impact on the baseline flood risk at River Pinn resulting from the Ickenham Stream diversion in London				
Client	Environment Agency	Date	19/07/2019	Version	1.0
Reviewer	Rita Farkas	Checker	Siliva Garratini	Approver	Laura Baird

Model Originator	Ramboll, Skanska	Date	May 2019
Software	ESTRY-TUFLOW		
Available models	Baseline, Concept Design and a Temporary scheme and sensitivity runs		
Model Reviewed	Baseline, Concept Design and Temporary scheme		
Model Reports	Flood Levels Analysis Report - River Pinn and Ickenham Stream_FinalV3-signed.pdf		
Guidance	Environment Agency Management System – Operational Instruction (379_05) Computational Modelling to assess flood and coastal risk.		

CONTENTS

	RECOMMENDATIONS
RED	Remedial action required
AMBER	Improvements recommended
GREEN	Satisfactory, compliant with guidance
GOLD	Exemplary practice and/or exceeds standard required

1. MODEL OVERVIEW

1.1 Model Extent & Description

This technical report, by Jacobs for the Environment Agency, describes the review of the hydraulic modelling approach outputs for the Ickenham Stream watercourse diversion into the River Pinn at Ruislip Golf Course in Ickenham. The model extent is shown in Figure 1.

Ramboll have been appointed by Costain-Skanska Joint Venture (CSVJ), working on behalf of High Speed 2 (HS2) for the Enabling Works South contract. Ramboll have built a hydrodynamic model for the Ickenham Stream watercourse diversion into the River Pinn at Ruislip Golf Course, Ickenham. The purpose of the hydraulic modelling was to assess the impact on flood risk within the River Pinn catchment from diverting all flows within the Ickenham Stream north of the HS2 line into the River Pinn.

In accordance with the project brief and scope, two diversion schemes have been simulated. A Concept Design scenario for the permanent watercourse diversion (shown in Figure 2), and a Temporary scenario for the temporary diversion scheme (shown in Figure 3), which will only be in place for a few years while the Ruislip Golf Course is closed for the HS2 Main Works.

The model is a 1D-2D Estry-Tuflow model which was developed from an existing 1D-2D ISIS Tuflow model of the River Pinn and all its tributaries, provided by the Environment Agency (EA ISIS-TUFLOW 2016 model). The updates included:

- truncating the model to the area of interest,
- conversion of 1D model from ISIS to ESTRY,
- updates to River Pinn cross-section data with new survey data obtained in December 2018,
- expansion of model domain to incorporate Ickenham Stream, utilise new cross-section survey data of the Ickenham Stream obtained in December 2018,
- inclusion of drainage channels,
- updates to the hydraulic boundary inflows and updates to the baseline model topography, with the most recent LiDAR data available.

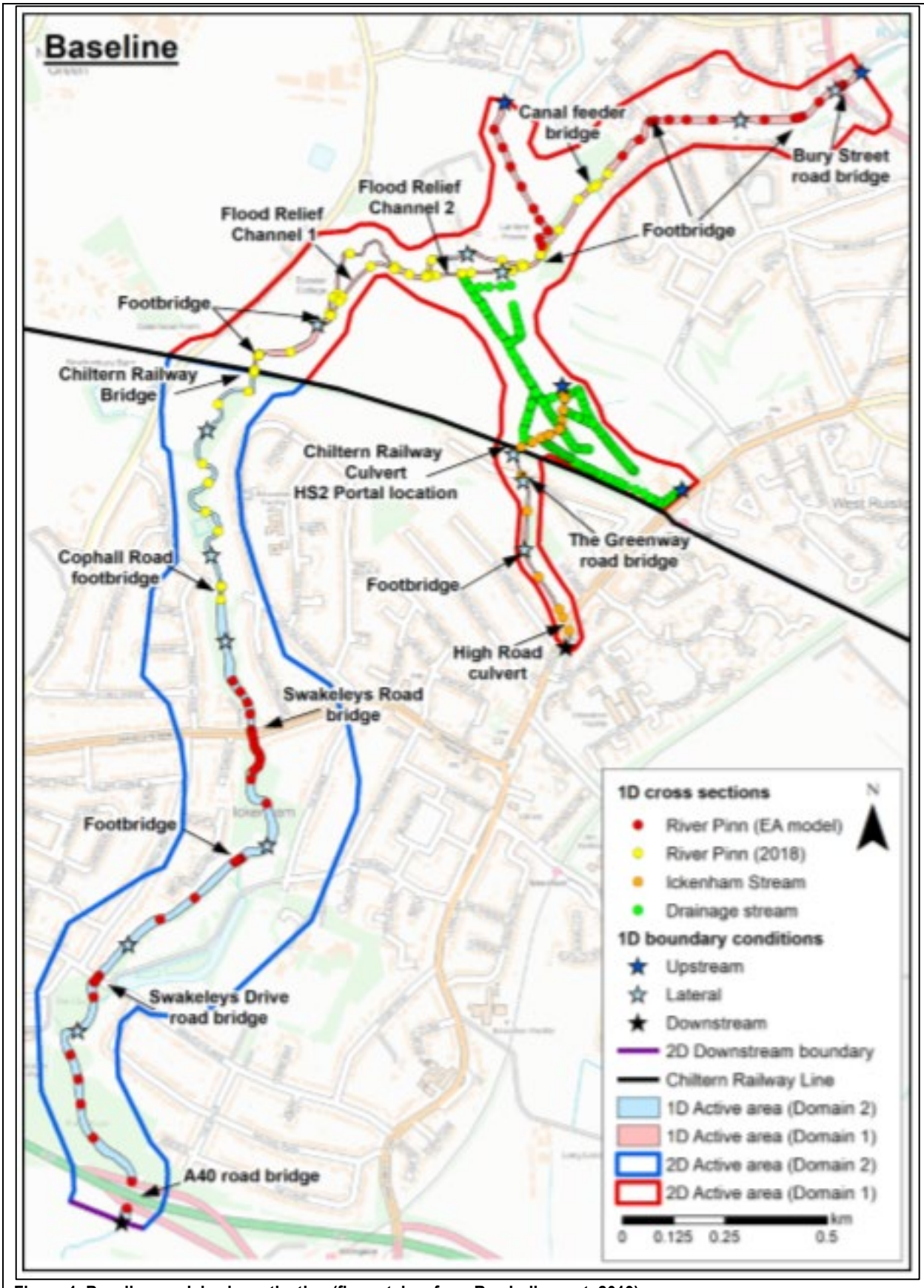

Figure 1. Baseline model schematisation (figure taken from Ramboll report, 2019)

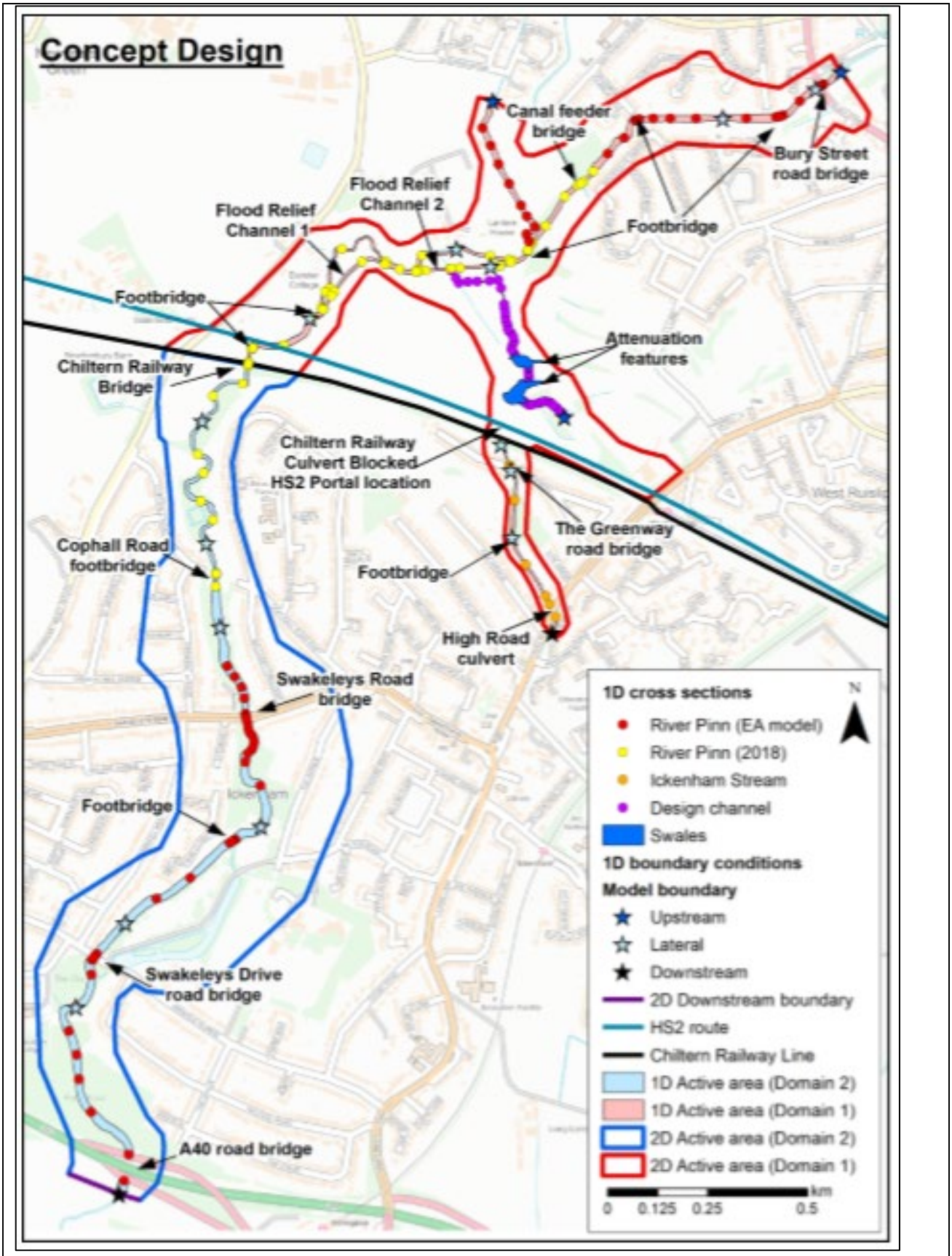

Figure 2 Concept design model schematisation (figure taken from Ramboll report, 2019)

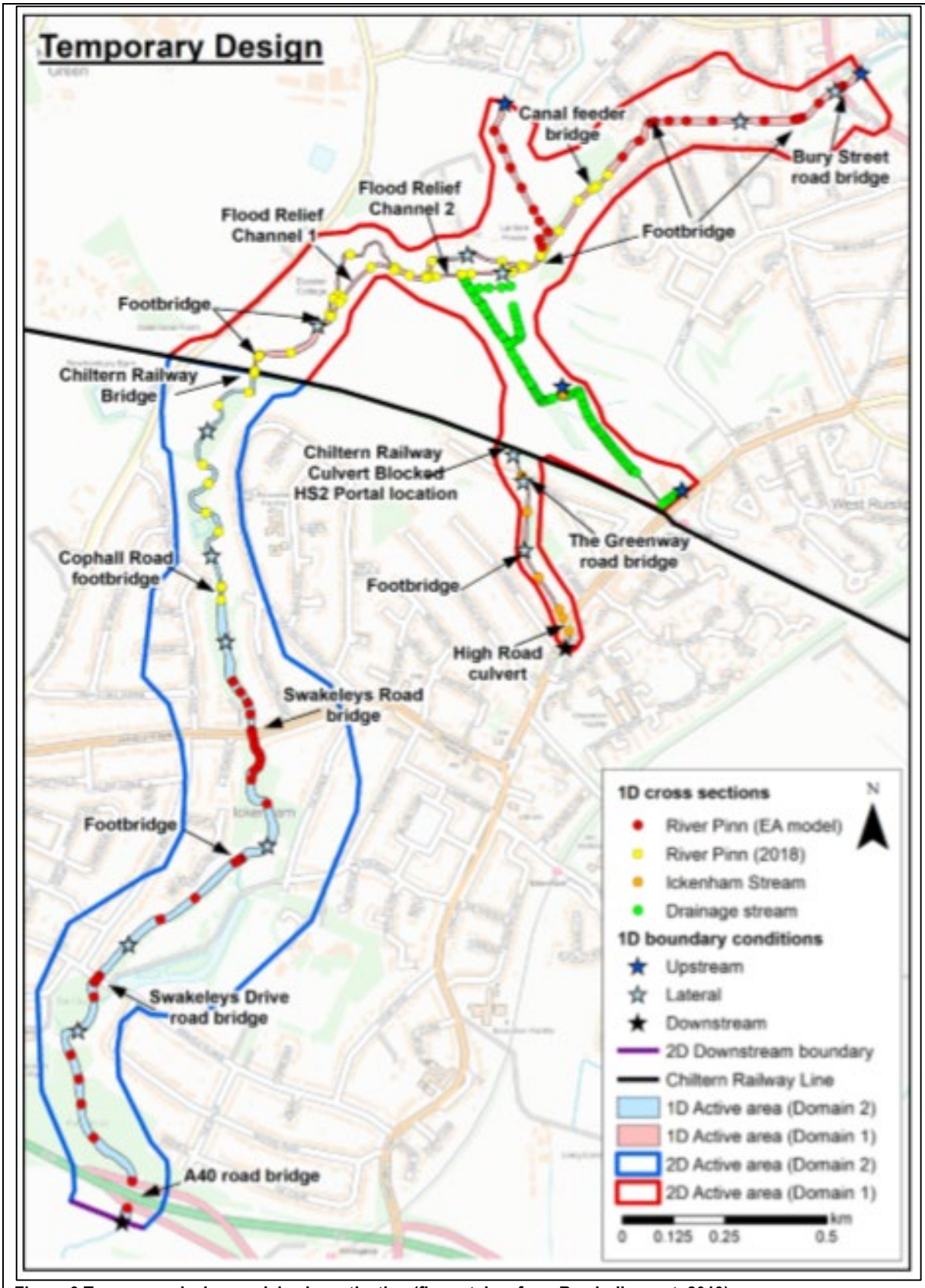

Figure 3 Temporary design model schematisation (figure taken from Ramboll report, 2019)

1.2 Model Summary

ESTRY-TUFLOW model to understand the impact on flood risk from diverting the Ickenham Stream into the River Pinn.

Two diversion schemes have been modelled. The ‘concept design’ scenario is for the permanent watercourse diversion, and a ‘temporary works’ scenario for the temporary diversion scheme.

1.3 Known issues prior to audit

N/A

2. IN-BANK REPRESENTATION			Action RED: Action required AMBER: Action recommended GREEN: Satisfactory GOLD: Exemplary practice
2.1 Cross-sections			Recommendation
	Pass	Fail	**NO ACTION REQUIRED**
Geo-referencing available?	Pass.		
Model chainage reasonable for channel length /sinuosity?	Pass.		
X-Section spacing appropriate (including interpolates)?	Pass.		
Top of bank markers correctly used?	N/A		
Panel markers used (if required)?	N/A		
2.2 In-channel roughness			Recommendation
	Pass	Fail	**NO ACTION REQUIRED**
Roughness values within expected range	Pass. The used 1D roughness values are 0.042 for River Pinn, 0.040 for Cannon Brook, 0.050/0.06 for Ickenham Stream and 0.050 for Drainage Ditches. These values appear to be appropriate.		
Roughness values show acceptable changes along reach	Pass.		
Roughness values justified through site evidence	Manning's n roughness values for the River Pinn were carried forward from the EA ISIS-TUFLOW 2016 model. Manning's roughness values for the Ickenham Stream and drainage channels		

	across the Ruislip Golf course were informed from site visits and survey data as stated in the report.		
Roughness values modified during calibration	The 2016 study carried out testing for model calibration. The values have been carried forward and applied in the 23480_EST model.		

3. OUT OF BANK REPRESENTATION			Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice
3.1 Out of bank approach & schematisation			Recommendation:
Extended x-sections checks	Pass	Fail	N/A
Discretisation too sparse/too detailed.	N/A		
Extended sections used for embanked watercourses?	N/A		
Extended sections used where depth of flooding excessive?	N/A		
Extended sections not orthogonal to flow direction and/or intersecting	N/A		
Sections not sufficiently extended/glass-walling	N/A		
Evident discrepancies/step between channel and extended section data.	N/A		
With / without-defences / scheme option scenarios appropriately represented?	N/A		
1D Floodplain reservoirs	Pass	Fail	N/A
Are reservoirs used where downstream gradient excessive?	N/A		
Are reservoirs excessively large/small?	N/A		
Are reservoir boundary consistent with ground topography?	N/A		
Are there sufficient number of connections / spills between channel and reservoirs and between reservoirs?	N/A		

Do reservoirs glass-wall?	N/A		
Is there are duplication / overlapping reservoir or extended cross-sections (double-counting)?	N/A		
2D Floodplain	Pass	Fail	**NO ACTION REQUIRED**
Is number of domains appropriate?	Pass. Two domains.		
Is grid orientated appropriate?	Pass. Orientation is appropriate.		
Is cell size appropriate?	Pass. The final model grid size is 2 m for dom1 and 4 m for dom2.		
Are 2D domain boundaries tied into topography?	Pass. The 2D domain is big enough.		
Is connectivity approach to 1D open channel suitable (e.g. HX, SX)?	Pass. HX, CN and SX lines appear to be appropriate.		
Is frequency of open channel connections appropriate?	Pass.		
Is connectivity at structures/culverts appropriate?	Pass. HX, CN and SX lines appear to be appropriate.		
Are floodplain features included as z-lines?	Pass. Bank top elevations are included in the as z-lines, bridge tops as z-shapes. Channels, other bridges, channels and swales are included with ascii grid using the Read Grid Zpts command.		
Is channel area deactivated?	Pass.		
Is there any duplication or missing floodplain (eg	Pass.		

x-sections extend into 2D)?			
3.2 Top of Bank Representation			Recommendation
	Pass	Fail	**NO ACTION REQUIRED**
Has best use been made of available data (E.g. AIMS) to define bank top crests?	Pass. The 23480_EST model has updated the terrain representation using 50 cm composite filtered LiDAR from the EA, downloaded in December 2018. The representation of the River Pinn uses cross-section data carried forward from the EA ISIS-TUFLOW 2016 model and new cross-section survey data for the River Pinn (December 2018).		
Has sufficient data consistency checks of bank top levels been undertaken and actioned (e.g. Lidar versus survey)?	Pass. A ground truth assessment was completed to check the levels using Survey Data completed for the Ickenham Stream (2018) across the golf course. Point inspection found a difference of less than +/- 0.05 m at the open floodplain. In contrast, the Ickenham Stream survey-2018 levels of the channel bed were on average 0.1 m lower than that captured by the LiDAR data. Therefore, the LiDAR data has been used with all bed levels lowered by 0.1 m.		
Are bank top spill coefficients appropriate?	N/A		

3.3 Out of Bank Roughness			Recommendation
	Pass	Fail	**NO ACTION REQUIRED**
Are roughness values within expected range?	Pass. The 2D roughness values were carried forward from the EA ISIS-TUFLOW 2016 model.		
Have any floodplain roughness values being transposed in-channel?	N/A		
Have roughness values been modified as part of model proving?	N/A Inherited from previous study.		

4. STRUCTURES			Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice
4.1 Structures includes/excluded			Recommendation
	Pass	Fail	**NO ACTION REQUIRED**
Has list of included / excluded structures been supplied?	Pass. Just list of included structures has been provided. Spot check from Google Maps did not identify any missing structure.		
Are excluded structures sufficiently justified?	No structure appears to be missing.		
Are any key structures missing?	Pass.		
Are structures included unnecessarily?	Pass.		
4.2 Structure Representation			Recommendation
	Pass	Fail	**NO ACTION REQUIRED**
Are structures units used appropriate?	Pass. Spot checked the Bury Steer flat deck Road Bridge, the footbridge upstream of Railway Bridge, the Chiltern Railway Bridge and the culvert under A40 road bridge.		
Are spills around structures included?	Pass. For most of the bridges, spills are included in the 1D, and there are three bridges for which spills are included in the 2D model.		
Are inlet and exit losses included for culverts?	Pass.		
Are structures appropriately	Pass.		

connected to open channel?			
Are 1% AEP head losses across structures reasonable?	Pass.		
Are losses for changes in culvert geometry / direction included?	N/A		
Do structures details match survey drawings (sample check)?	Pass. Checked the Bury Street Road Bridge, the Footbridge in Ruislip Golf Course, the Chiltern Railway Bridge and the culvert under A40 road bridge.		
Are structures coefficients and modular limits within expected range?	Pass.		
Is use of different coefficients / modular limits for very high/low AEP's justified?	N/A		
Are control rules appropriate?	N/A		

5. BOUNDARIES			Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice
5.1 Fluvial Inflow Boundaries			Recommendation
	Pass	Fail	N/A.
Has a separate hydrology review been undertaken?	Please see accompanying hydrology review.		
Is there clear provenance of inflows used?			
Are point and lateral inflow clearly distinguishable?			
Is location of inflows in close proximity to key structures justifiable?			
Have range of storm duration been assessed?			
Have peak flows and volumes been assessed?			
Are minimum flows / sweetening flows appropriate?			
5.2 Pumped Inflows			Recommendation
	Pass	Fail	N/A
Are pump units/abstraction units adopted appropriate?	N/A		
Have cut-offs been included?	N/A		
Are pump rules appropriately simplified?	N/A		

5.3 Downstream Boundary			Recommendation
	Pass	Fail	**ACTION SUGGESTED** Clarification on whether sensitivity on downstream boundary has been tested is required.
Is downstream boundary unit and location appropriate?	Pass. The two fixed water level downstream boundaries are modelled as water level-flow (HQ) boundaries both in the 1D and 2D network, Pinn_DS and Ick_DS.		
Has sensitivity to d/s boundary been quantified?		Unclear whether sensitivity on downstream boundary has been tested, as results were not provided but it is included in the file logs table. Clarification is required.	
Has phasing of d/s boundary relative to inflows been appropriately addressed?	N/A		

6 CALIBRATION, VERIFICATION, SENSITIVITY & UNCERTAINTY			Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice
6.1 Calibration and Verification			Recommendation
	Pass	Fail	**ACTION REQUIRED** The model has changed substantially since 2016, therefore recalibration is required.
Has selection of events used been appropriately justified?	The Environment Agency ISIS-TUFLOW was calibrated in 2016 and design inflows verified through comparison with statistical estimates at selected check-points. Validation undertaken by Ramboll comprised comparison of the 2016 and 2019 model results for the 50% and 1% AEP events. This comparison showed that the 2019 results were lower and flood extents were smaller. Ramboll acknowledge these differences and note that future studies will need to assess these differences. Ramboll defend the validity of the 2019 model because it has been used solely to determine the relative impact of the proposed diversion. The 2019 model is a substantial update to the 2016 model including conversion from ISIS to ESTRY, addition of new hydraulic reaches in the key area of interest and new floodplain data. These changes are acknowledged to result in less flooding than the 2016 model. Without this revalidation there is risk that the relative differences (baseline versus diversion) are not robust. As a minimum the design flows should be compared with the statistical estimates at the check points. It is desirable that calibration events be rerun to demonstrate that the 2019 model is robustly validated.		
Has best use of available data been made?			
Does model replicate events data satisfactorily?			
Has frequency of onset of flooding been appropriately justified?			
Have animations been used to verify flooding mechanism?			
Has calibration knowledge been appropriately transferred to design events?			
Has sensitivity knowledge been appropriately transferred to design events?			

6.2 Sensitivity and Uncertainty			Recommendation
	Pass	Fail	**NO ACTION REQUIRED.**
Has appropriate sensitivity analysis been undertaken?	Sensitivity analysis on +/-20% Manning's n roughness has been undertaken. Sensitivity to the downstream boundary is recommended above.		
Has model uncertainty been quantified?	Pass.		
Have key model assumptions been clearly listed?	Pass.		

7. MODEL STABILITY & RUN PARAMETERS			Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice
	Pass	Fail	**NO ACTION REQUIRED**
Has the model been run for long enough?	Pass, 30 hours.		
Is time step appropriate?	Pass, 0.5 s for the 1D and 1 s for the 2D.		
Are the simulation parameters within acceptable limits?	Pass.		
Are run-times acceptable?	Pass. 30 model hours took approximately 3 hours to run for the baseline 1% AEP scenario.		
Are changes in run parameters for different AEP's justified?	Pass. The depth limit factor has been raised from 10 to 50 from the 0.5% AEP event for stability purposes.		
Does model show acceptable numerical stability /mass balance?	Pass. A spike is observed in the 1D ESTRY domain at the start of the simulation, peaking at 0.14%, but this quickly returns to oscillate around 0%. A spike is observed in the 2D TUFLOW domain in domain1. This peaks at approximately 2.2%, but returns to zero before the flood peak.		

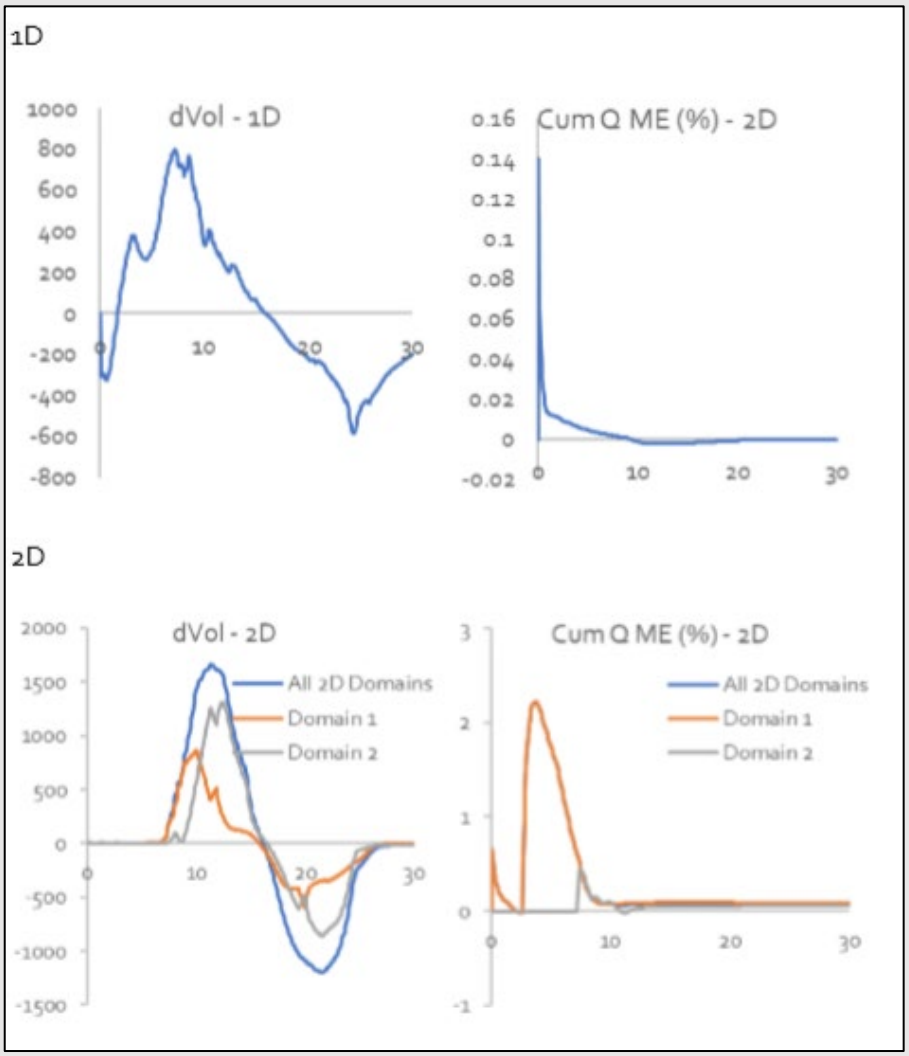

Figure 4: Mass balance plots for the 1% AEP event from Ramboll Modelling report, 2019

Have any parameter changes to address model instability been appropriately justified?	Pass. No change.	
Are 2D stability patches located in key areas?	Pass. No stability patch in the model.	
Are initial conditions appropriate?	Pass.	

8. RESULTS			Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice
	Pass	Fail	**NO ACTION REQUIRED**
Are peaks level/flows associated with initial conditions	Pass.		
Do peak levels / outlines increase with event severity in logical way?	Pass.		
Are anomalous results sufficiently explained in accompanying report?	Pass, no anomalous results.		
Do peak levels, flows, velocities seem realistic?	Pass.		
Are key results (peak water levels & outlines) clearly presented and understandable for non-modellers	Pass. Flood depths increase progressively with event severity. The model results indicate that the Ickenham Stream Diversion, following either the Concept Design channel or the Temporary channel, will not increase flood risk along the River Pinn. The model results show that the Concept Design channel reduces the flood risk, across the Ruislip Golf Course by working with the topography of the land and attenuating flows at key locations. Blockage of the Chiltern Railway culvert results in increased water levels in the Ickenham Stream downstream of the Chiltern Railway		

	Line however, the modelling indicates that this increase does not contribute to flood risk as water levels remain in channel and do not exceed channel bank levels.		

9. OTHER CONCERNS	Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice
Note- HS2 lines has not been modelled and therefore further review of the models will be required.	**ACTION SUGGESTED** Testing of storm duration is recommended to ensure the swales are appropriately designed.
The concept design scenario for permanent diversion of the Ickenham Stream includes blocking of the Chiltern Railway Culvert. The difference between the baseline and concept design setup are limited to the Ruislip Golf Course area. Two wide and oversized swales have been included in the concept design for the Ickenham Stream. These act as attenuation features, helping to control the flow routed down the watercourse diversion, by providing areas where water will pond. Testing of storm duration is recommended to ensure the swales are appropriately designed.	
The temporary diversion scenario blocks specific channels of the Ickenham Stream that allow flows to pass under the Chiltern Railway Culvert and diverting flows upstream of the Chiltern Railway Line along the existing drainage channels connecting the Ickenham Stream to the River Pinn. The difference between the baseline and temporary scenario setup are limited to the Ruislip Golf Course area.	

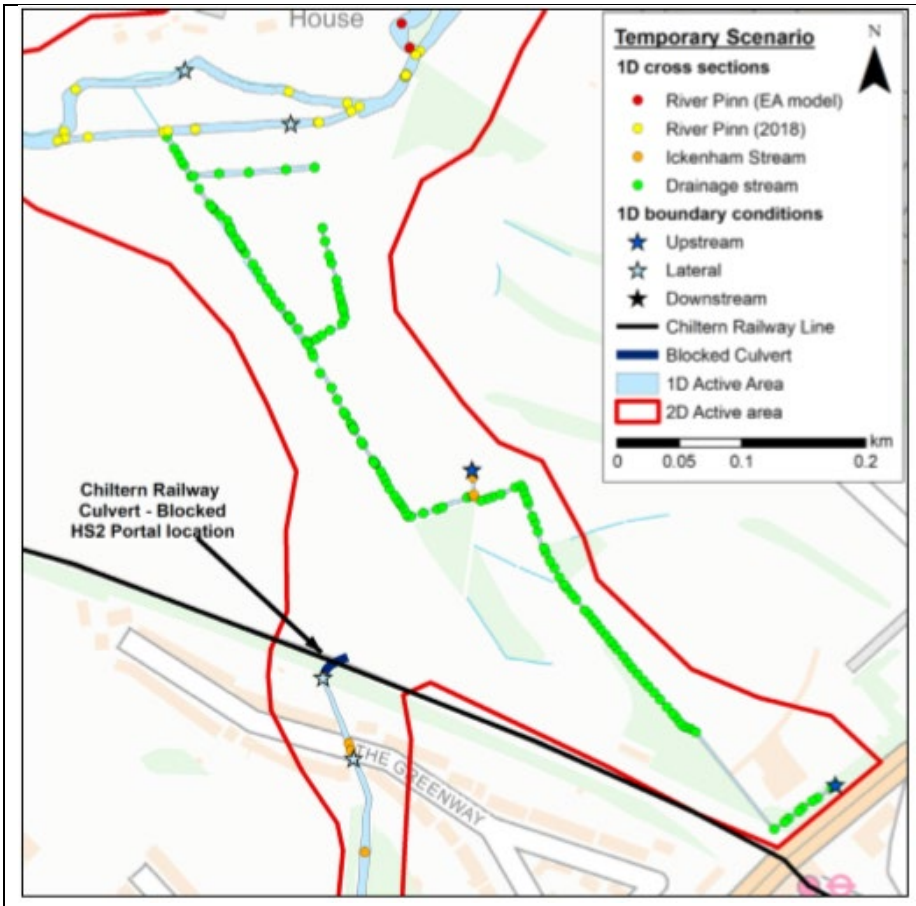

Figure 5 Temporary design model schematisation

10. COMPLIANCE WITH GUIDANCE	Yes/No
Environment Agency Management System – Operational Instruction (379_05) Computational Modelling to assess flood and coastal risk.	**Yes**
Flood Modeller on-line manuals (Version 4.0)	**N/A**
TUFLOW manual (version 2016-10-AB)	**Yes**

11. MODELLING APPROACH DISCUSSION
The modelling approach used (1D-2D model) is considered appropriate for the purpose of the study.

12. KEY FINDINGS AND RECOMMENDED ACTIONS	Action RED: Action required AMBER: Action recommended GREEN: satisfactory GOLD: Exemplary practice

The model approach used (1D-2D model) is considered appropriate for the purpose of the study.	**NO ACTION REQUIRED**
The following actions are suggested: • Clarification on whether sensitivity on downstream boundary has been tested is required. • Testing of storm duration is recommended to ensure the swales are appropriately designed.	**ACTION SUGGESTED**: Please see requirements in the adjacent cell.
The following actions are required: The model has changed substantially since 2016. Comparison of 2016 and 2019 results demonstrates that 2019 flood depths are lower and flood extents are smaller. Whilst the purpose of the 2019 model is to investigate relative differences between the baseline and diversion scenarios there is risk that under-estimation by the 2019 model undermines confidence in the relative difference. Ideally the 2019 model should be recalibrated. As a minimum, comparison of the design flows with the statistical flood frequency check points is needed.	**ACTION REQUIRED:** Please see requirements in the adjacent cell.