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High Speed Two Phase 2a (West Midlands - Crewe)

Background Information and Data

CA1: Fradley to Colton

Hydraulic modelling report - Pyford Brook (BID-WR-004-001)

July 2017

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Department for Transport

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1 Introduction

1.1 Background

1.1.1 This document presents the results of the hydraulic modelling carried out in the Fradley to Colton area (CA1) relevant to High Speed Rail (West Midlands - Crewe). The following hydraulic modelling reports are also relevant to the Fradley to Colton area:

- Hydraulic modelling report - River Trent and Bourne Brook (Background Information and Data 004: BID-WR-004-002);
- Hydraulic modelling report - Moreton Brook (Background Information and Data 004: BID-WR-004-003); and
- Hydraulic modelling report - Stockwell Heath (Background Information and Data 004: BID-WR-004-004).

1.1.2 The water resources and flood risk assessment is detailed in the High Speed Rail (West Midlands - Crewe) Environmental Statement (ES)[1]. Volumes 2, 3 and 4 discuss water resource and flood risk effects and Volume 5, Appendices sets out the following relevant to the Fradley to Colton area:

- a route-wide Water Framework Directive compliance assessment (Volume 5: Appendix WR-001-000);
- a water resources assessment (Volume 5: WR-002-001);
- a flood risk assessment (Volume 5: WR-003-001); and
- a route-wide draft water resources and flood risk operation and maintenance plan (Volume 5: Appendix WR-005-000).

1.2 Aims

1.2.1 The Proposed Scheme includes a number of locations where the route will cross watercourses and their floodplains. The Proposed Scheme crossing locations have the potential to increase flood risk where they restrict flood flows or change floodplain dynamics.

1.2.2 At the locations detailed in this report, the route will cross Pyford Brook on the proposed Pyford Brook viaduct.

1.2.3 A hydraulic model of Pyford Brook was created to simulate the risk of flooding in this location for an approximate 2.7km stretch of the brook, also incorporating an unnamed drain downstream. This report documents the methods used and discusses the results, assumptions and limitations imposed by them.

[1] HS2 Ltd (2017), *High Speed Rail (West Midlands - Crewe) Environmental Statement (ES)*, www.gov.uk/hs2

1.2.4 Hydraulic models of the existing conditions and with the Proposed Scheme included have been evaluated to assess the impact of the Proposed Scheme on flood risk and to derive peak flood water levels relative to the proposed structures.

1.2.5 This report details the existing hydrological and hydraulic processes of the reaches modelled and how these will be affected by the Proposed Scheme.

1.3 Objectives

1.3.1 The objectives were to:

- conduct, where feasible, a site visit to inform understanding of existing conditions, including existing channel and floodplain characteristics, hydraulic structures and flow paths;
- estimate flow hydrographs at the Proposed Scheme crossing locations;
- develop a hydraulic model, commensurate with the level of detail required and available at this stage, to provide peak levels at key structures for the Proposed Scheme, based on the most suitable data available and flow hydrographs developed; and
- analyse the impact of the Proposed Scheme on flood risk levels obtained from the results of the following Annual Exceedance Probabilities (AEP): 50%, 20%, 5.0%, 1.33%, 1.0%, 1.0%+climate change (CC), 0.5% and 0.1%.

1.4 Justification of approach

1.4.1 The hydraulic model has been constructed to provide an awareness of existing flood risk to inform the Proposed Scheme design. The detail included identifies potential impacts of the Proposed Scheme on surrounding land and to ensure that 0.6m freeboard to soffit is provided in a 1% +CC AEP event and 1.0m freeboard to track level is provided in a 0.1% AEP event.

1.4.2 A 2D hydraulic model was selected for this study as detailed 1D channel information was not available at the time of study and the Light Detection and Ranging (LiDAR) survey adequately portrayed the existing channels and features. Using a 2D approach allows for structures to be represented using the ESTRY solver within Two-dimensional Unsteady FLOW (TUFLOW).

1.4.3 Due to the Proposed Scheme crossing the floodplain on a viaduct, and thus causing a high level of risk for the design of the project and its impact on the environment, it was proposed that hydrological calculations be undertaken to a full level of detail. This considered Flood Estimation Handbook (FEH) Statistical, Revitalised Flood Hydrograph 2 (ReFH2) and the hybrid methods. This is particularly relevant in this location where both abutments are driven by flood risk.

1.5 Scope

1.5.1 The scope of the study is to undertake hydraulic modelling to enable an assessment to be made of the impact of the Proposed Scheme on the local environment. The models should be detailed enough to allow future assessment of different options associated with each crossing location, to allow the management of flood risk and correct sizing of crossing openings.

1.5.2 The report focuses upon:

- discussion of all relevant datasets, quality and gaps;
- hydrological analysis undertaken, approach used and calculation steps;
- integration of the hydrological analysis with the hydraulic modelling;
- hydraulic modelling methodology chosen, with clear identification of general methodologies and justification; and
- hydraulic modelling parameters, assumptions, limitations and uncertainty.

2 Site characteristics

2.1 Description of the study area

Model reach

2.1.1 The section of Pyford Brook being modelled is located approximately between Wood End Lane and Alrewas Hayes. Figure 1 shows the modelled extent, with the model upstream boundary of the model located close to Fradley, approximately 90m upstream of Wood End Lane. The downstream boundary is located approximately 60m downstream of Alrewas Hayes. Approximately 2.75km of Pyford Brook has been modelled.

2.1.2 Within the study area, there are four isolated properties including Wood End Farm located approximately 120m from the upstream model extent. Wood End Lane is the main transport infrastructure in this area forming the most upstream crossing over Pyford Brook in the modelled extent. At the downstream end of the model, there is an existing access track which will be used for access to the Proposed Scheme. This crosses both Pyford Brook and an unnamed land drain approximately 380m upstream of the Ashby Sitch and Pyford Brook confluence. The other Pyford Brook crossing in this area is the Trent and Mersey Canal on an aqueduct over the watercourse. Alrewas Hayes is a property at the downstream extent of the modelled reach. Pyford Brook runs along the northern boundary of this property with Pyford Brook culverted underneath the access track to the property.

2.1.3 There are a number of water bodies within the area of interest. There are three ponds located approximately 40m downstream of the proposed crossing on the right bank of the channel. Approximately 200m east of the proposed Pyford Brook viaduct, on the left bank, there is a larger water body that appears to drain into the main watercourse through a culvert that outfalls just downstream of the proposed Pyford Brook viaduct.

2.1.4 The catchment size at the downstream model extent is 18km^2 and is ungauged. The proposed Pyford Brook viaduct is located approximately 4.4km upstream of the confluence with the River Trent and it is therefore assumed that the Trent will have no impact on peak flood levels at Pyford Brook in this location.

2.1.5 There is a section of channel underneath the proposed Pyford Brook viaduct that appears to have been artificially straightened.

2.1.6 An unusual feature was identified from aerial photography towards the downstream extent of the model, approximately 300m north of the property Alrewas Hayes. It appears from the LiDAR survey to be two embankments in the corner of a field. Refer to Section 4.2.7 for details on the representation of these features.

Hydrological description

2.1.7 Pyford Brook originates in the Leomansley area to the west of Lichfield, Staffordshire.

2.1.8 The catchment area contributing to the downstream boundary of the proposed hydraulic model is $18.0km^2$ and is heavily urbanised.

2.1.9 There are no gauging stations present within the Pyford Brook catchment.

2.1.10 Standard annual average rainfall for the catchment at the model downstream boundary is 681mm.

Railway alignment

2.1.11 The route of the Proposed Scheme crosses the study area from the south-east before crossing over Pyford Brook at Fradley on the proposed Pyford Brook viaduct. The alignment then continues to the north-west. Further detail on the Proposed Scheme can be found in Maps CT-06-201 and CT-06-201-R1 in the Volume 2 Map Book.

Flood mechanisms

2.1.12 The flood zones are confined closely to the main channel for the majority of the straightened channel section but towards the downstream model extent, the floodplain flows diverge from the main channel towards Ashby Sitch.

2.1.13 The Environment Agency flood zones do not show any water backing up behind Wood End Lane Culvert or the Trent and Mersey Canal aqueduct upstream of the proposed viaduct, but the updated Flood Map for Surface Water (uFMfSW) shows a significant amount of water back up behind both of these receptors. This is a known limitation of the approach taken by the National Generalised Modelling.

2.1.14 An additional floodplain flow path can be seen from the uFMfSW on the left bank, underneath the proposed Pyford Brook viaduct, refer to Figure 1.

2.2 Existing understanding of flood risk

Sources of information

2.2.1 Sources of Environment Agency data were assessed as below:

- Flood Map for Planning (Rivers and Sea)[2]; and
- updated Flood Map for Surface Water (uFMfSW)[3].

2.2.2 The proposed Pyford Brook viaduct spans Flood Zones 2 (0.1%AEP) and 3 (1.0% AEP) of the Environment Agency Flood Map for Planning as shown in Figure 1.

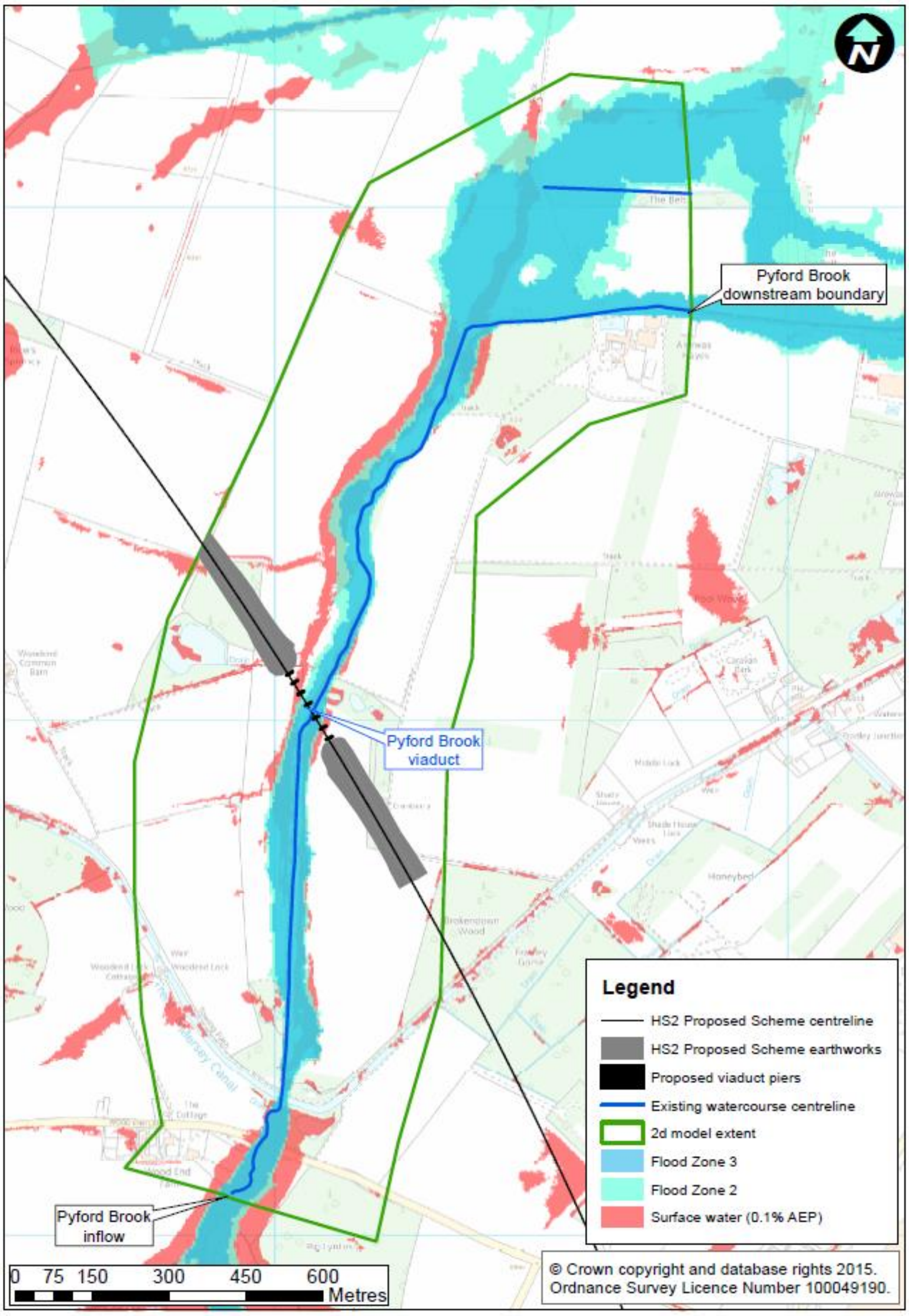
[2] Gov.uk, *Flood map for planning*, https://flood-map-for-planning.service.gov.uk
[3] Gov.uk, *Long term flood risk information*, https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?map=SurfaceWater

2.2.3 The uFMfSW shows that the main flow paths are confined largely to the channel, with an additional flow path identified as in 2.1.13.

2.2.4 Available information does not indicate the presence of any flood defences within the model extent.

2.2.5 The Environment Agency flood maps are believed to be derived from National Generalised Modelling.

Figure 1: Environment Agency Flood Zones 2 and 3 and uFMfSW (0.1%AEP) at Pyford Brook



2.3 Availability of existing hydraulic models

2.3.1 An existing hydraulic model was supplied by HS2 for this study.

2.3.2 The model provided was a 1D (Flood Modeller) only model received in 2016. The model was developed in 2016.

2.3.3 The model was developed on behalf of HS2 Ltd. for HS2 Phase One and modelled a section of the watercourse upstream of the Phase 2a model extent. This section of the watercourse is called Curborough Brook.

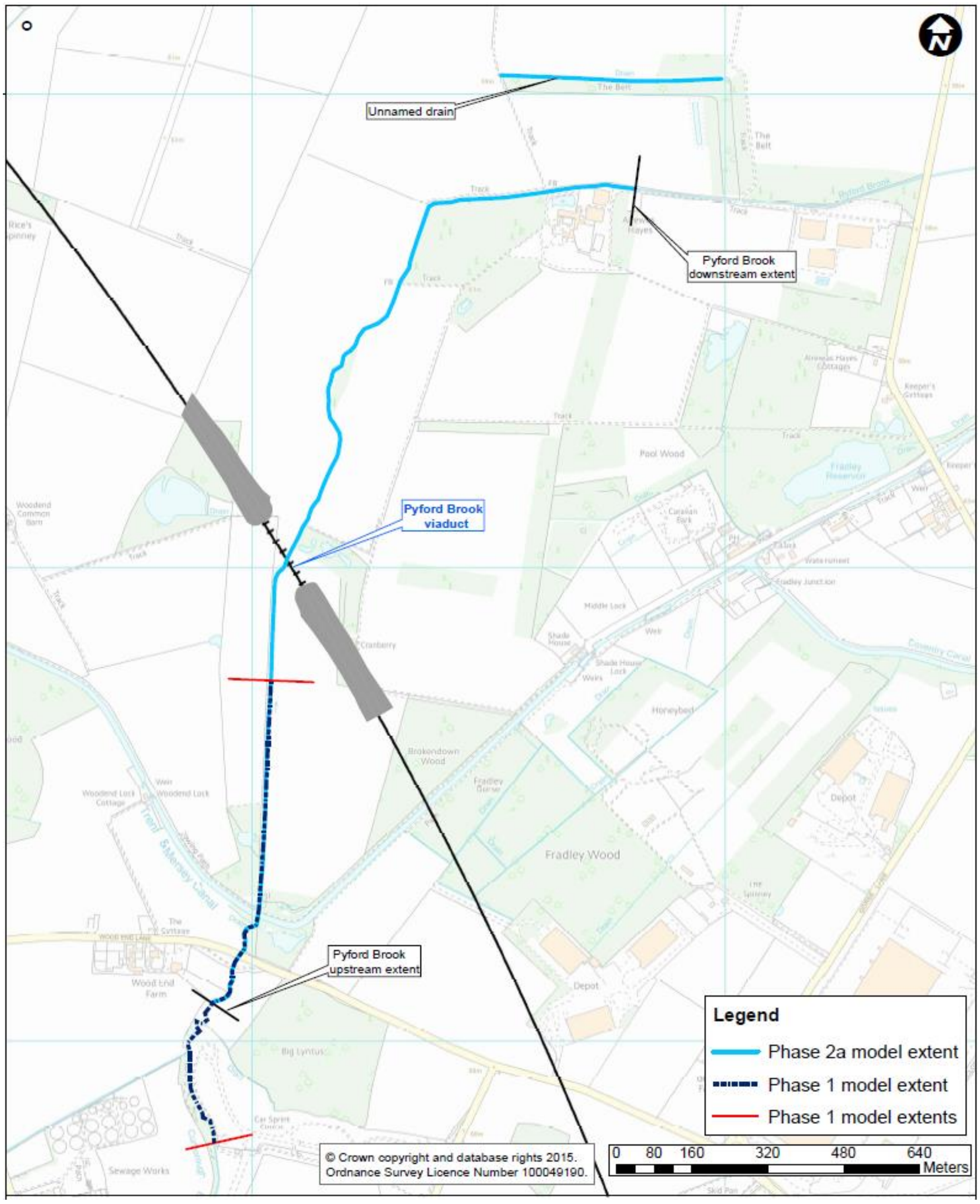
2.3.4 Curborough viaduct (for details refer to HS2 Phase One Environmental Statement Volume 5 Technical Appendices[4]) is located between Wood End Lane culvert and the Trent and Mersey Canal aqueduct.

2.3.5 The extent of the 1D model was sufficient for the Phase One viaduct but not suitable for Phase 2a as the downstream extent of the Phase One model is located upstream of the proposed Pyford Brook viaduct crossing.

2.3.6 Survey was available throughout the Phase One modelled extent, as seen in Figure 2.

[4] HS2 Ltd (2013), *High Speed Two (HS2) Phase 1 (London – west Midlands) Environmental Statement Volume 5 Technical Appendices*, http://webarchive.nationalarchives.gov.uk/20140810181713/http://assets.dft.gov.uk/hs2-environmental-statement/volume-5/water/WR-004-015.pdf

Figure 2: Comparison of Phase One and Phase 2a hydraulic modelling extent



2.4 Site visit

2.4.1 A site visit was undertaken in October 2016 to determine the dimension of the channel and existing infrastructure.

2.4.2 Several structures were visited along Pyford Brook, however not all could be visited due to site access restrictions and general accessibility issues. For the structures that were visited, images were taken to ascertain dimensions and roughness.

2.4.3 Eight structures were identified within the modelled extent. A section of Pyford Brook was visited between approximately 350m downstream of the Trent and Mersey Canal and approximately 75m downstream of the proposed Pyford

Brook viaduct along a length of approximately 2.02km of channel. Images were taken within this stretch.

2.4.4 A number of other structures were identified on site including two weirs located approximately 270m downstream of the Trent and Mersey Canal.

2.4.5 Pyford Brook was found to be uniform in the section downstream of the proposed Pyford Brook viaduct and appears to be an approximately 6-8m wide channel with the width of the channel bed approximately 4-5m. This provides a more accurate representation of the channel as the LiDAR shows a channel width of 8-14m throughout.

2.4.6 The westerly pond on the right bank is shown to have a 1m level difference between the pond and the embankment separating it from the watercourse channel. On the left bank, the aerial photography shows a drain from the pond that appears to discharge into Pyford Brook but the site visit confirmed that there is no flow from this pond so this has been omitted from the model.

3 Model approach and justification

3.1 Model conceptualisation

3.1.1 Model extents were carefully selected to ensure that the model boundaries did not have any impact on the flood extent in the area of interest.

3.1.2 Utilising a 2D approach is appropriate for this area as there was no survey data available for the majority of the watercourse extent. In addition, there are significant overland flow paths making this approach more appropriate because of the floodplain flow. Using a 2D approach allows more confidence in the flood extent under the proposed Pyford Brook viaduct which is important in this area as it defines the abutment positions and viaduct width.

3.1.3 The available Phase One model was used to provide dimensions for two of the structures, channel depth and the spill level of Wood End Lane to help inform the Pyford Brook hydraulic model. A number of cross-sections were cross-referenced.

3.1.4 Downstream of the viaduct, the model includes an existing access track crossing Pyford Brook that is proposed to be used by HS2 Ltd. for access to a balancing pond. There are two culverts under the track which are also included within the model.

3.2 Software

3.2.1 TUFLOW (2016-AA) has been used. This methodology is in line with standard practice to use the latest available build at the time modelling commenced, while TUFLOW is industry standard software.

3.3 Topographic survey

3.3.1 No additional topographic survey was commissioned for this study.

3.4 Input data

3.4.1 The elevation data for the study area was produced using 200mm LiDAR flown specifically for HS2 Ltd. and covers 500m either side of the route centreline. In addition, 2m LiDAR, provided by the Environment Agency, was used for the remainder of the modelled extent.

4 Technical method and implementation

4.1 Hydrological assessment

4.1.1 The estimation of design peak flows and hydrographs for Pyford Brook was based on the application of the methodologies pre-approved by HS2 Ltd. These are standard in the UK flood risk management industry.

4.1.2 The FEH methodologies were followed, in particular the Statistical Method. No suitable flow records are available in the study catchment, so the FEH Pooling Group methodology was adopted. This uses recorded river flows in hydrologically similar catchments to estimate flows at the subject location. The calculations were based on the most up-to-date national database available at the time of the undertaking the calculations. The data was obtained from the National River Flow Archive (NRFA) and/or HiFlowsUK.

4.1.3 In addition, the FEH Revitalised Rainfall Runoff Method, version 2 (part of ReFH2) was used to produce an alternative set of design peak flows and event probability. ReFH2 uses the recently updated FEH13 rainfall database and parameters. The calculations are based on relevant catchment descriptors of each catchment, which were obtained from the FEH Web Service database.

4.1.4 The two sets of design peak flows (from FEH Statistical Method and ReFH2) were analysed and compared, selecting the methodology that produced the most conservative river flows. The ReFH2 model using a summer profile is the preferred method for Pyford Brook, as the catchment is small and heavily urbanised.

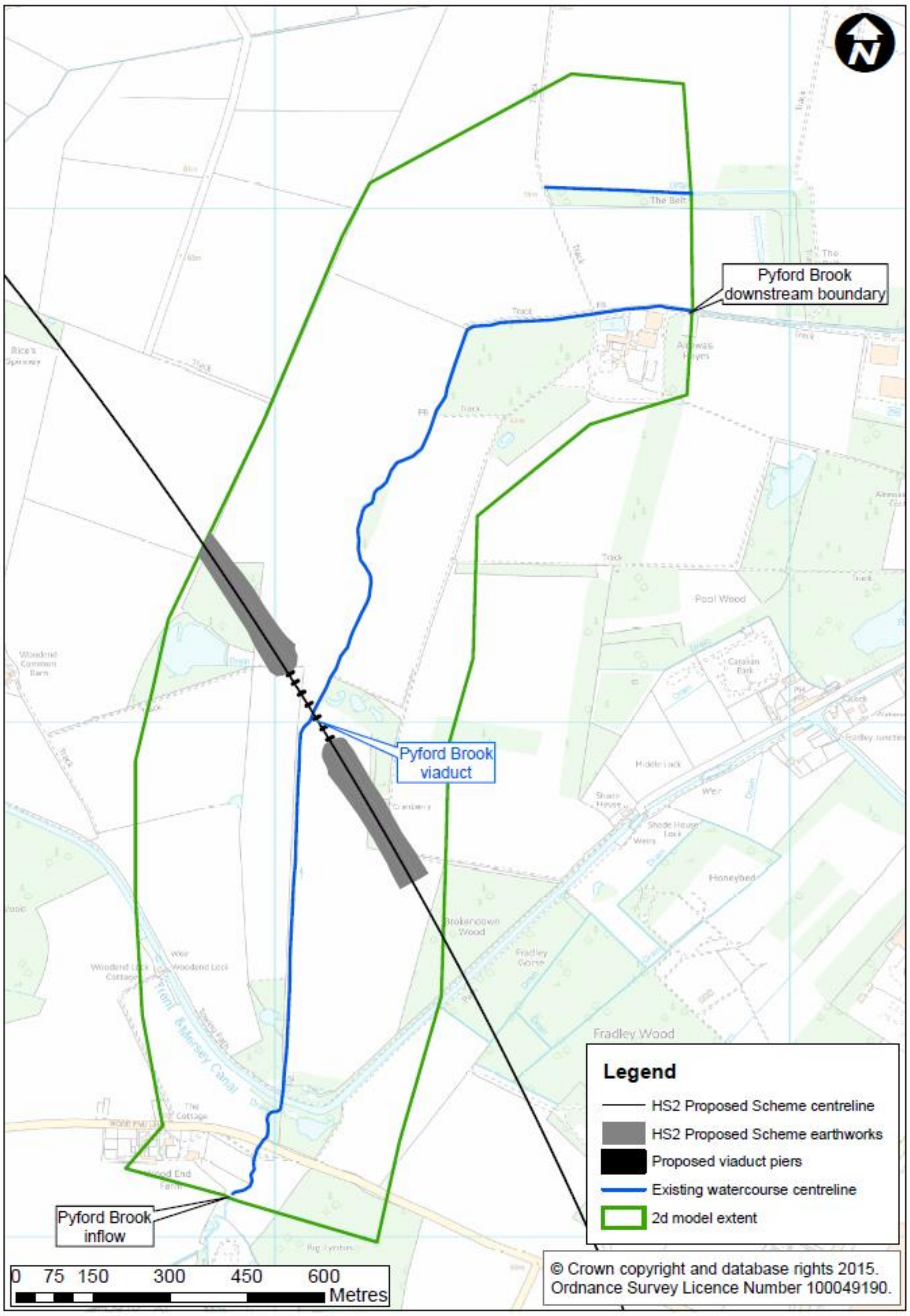
4.1.5 The design hydrographs used for the hydraulic modelling stage were generated using ReFH2 as the FEH Statistical method does not produce time series, just peak flows. The values were scaled so the peak flow for each return period matched that selected as the design value.

4.1.6 Table 1 shows the peak flows used for the computational hydraulic modelling work. Figure 3 highlights the inflow location and the associated river networks assessed as part of this study.

Table 1: Peak flows used for hydraulic analysis

	AEP	Return period	Site code Pyford Brook inflow
Flood peak (m^3/s)	50%	2yr	2.87
	20%	5yr	3.85
	5.0%	20yr	5.47
	1.33%	75yr	7.67
	1.0%	100yr	8.27
	1.0% + CC	100yr + CC	12.4
	0.5%	200yr	9.84
	0.1%	1000yr	14.07

Figure 3: Schematic of inflows and modelled river network



4.2 Hydraulic model build - baseline model

1D representation

4.2.1 Culverts were included in the ESTRY component of TUFLOW. Dimensions of Wood End Lane culvert and Trent and Mersey Canal aqueduct were set using the available survey from Phase One hydraulic model provided while the two downstream track culverts were estimated using available LiDAR.

2D representation

4.2.2 The cell size of the model was set as 2m. Cell size and alignment for the 2D model grid was optimised to ensure appropriate representation of the flow pathways whilst maintaining reasonable run times. The alignment for the 2D model grid follows the rotation of the Proposed Scheme piers.

4.2.3 Using cross-sectional data from the available Phase One survey, the channel has been defined along the whole extent to represent existing conditions.

4.2.4 A section of Wood End Lane was raised as it had been filtered out of the LiDAR and was therefore not accurately represented. The structure dimensions were taken from Phase One survey data and an area of the road crossing Pyford Brook was subsequently raised.

4.2.5 An initial water level was set in one of the ponds on the right bank to represent existing conditions. It was set at 1m below bank top, as observed on the site visit. An embankment was raised between the most westerly pond and the watercourse following a site visit observation. An embankment was also strengthened between both of the ponds due to poor LiDAR filtering. The most easterly pond on the right bank was excluded from the model because it is not hydraulically connected to the floodplain.

4.2.6 The embankments noted previously, located in a field at the downstream extent of the model, were present in 2005 aerial photography. However, aerial photography from 2013 shows that the embankments were flattened. Therefore, they were removed from the model.

Inflow boundaries

4.2.7 The study area has a single inflow for Pyford Brook, located 130m upstream of Wood End Lane. This is shown in Figure 3.

Downstream boundary

4.2.8 A normal depth boundary was used at the downstream extent of Pyford Brook, and also in the floodplain at the downstream extent. This generates a stage-discharge curve based on the bed slope which varies across the floodplain.

4.2.9 A normal depth slope of 0.04 m/m (1 in 25) was used within the channel and slopes of between 0.002 m/m (1 in 500) and 0.005 m/m (1 in 200) for the floodplain. These were derived from LiDAR.

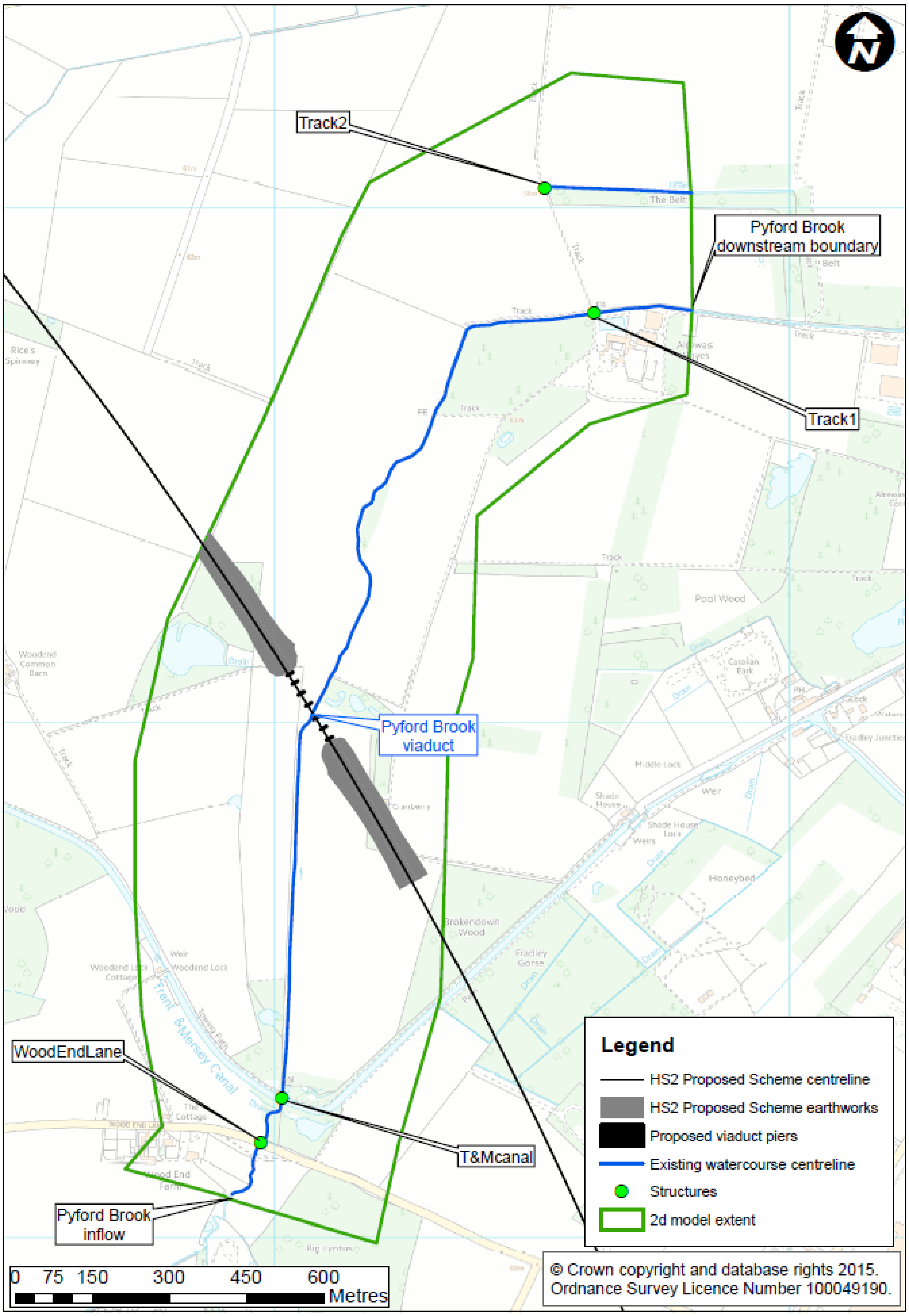
Key structures

4.2.10 There are a number of structures within the model extent that were modelled in a variety of ways. Additionally, there are a number of structures which are not modelled as no information is available. Those included in the model and deemed to be key hydraulic controls are detailed in Table 2. All structures, including key hydraulic controls, are shown in Figure 4.

Table 2: Key structures present within the modelled extent of Pyford Brook

Structure reference	Structure description	Modelling representation and justification
WoodEndLane	Large culvert under Wood End Lane. 22.0m (L) x 3.382m (W) x 1.2m (H)	Culvert modelled as rectangular. Dimensions taken from Phase One topographic survey
T&Mcanal	Large elliptical culvert under Trent and Mersey canal. 38.0m (L) x 2.03m (D)	Elliptical structure modelled as circular. Dimensions taken from Phase One topographic survey

Figure 4: Existing and proposed structures within the model extent



4.2.11 A pipe structure is located slightly upstream of Wood End Lane culvert. This structure has been omitted from the model as it is drowned at high flows and represented by the Wood End Lane soffit.

4.2.12 One weir was identified approximately 70m downstream of the Trent and Mersey canal with a depth of approximately 100-120mm. A second weir was identified slightly upstream of the first weir. It has a 100mm head at low water level and a pipe from the side at 100mm diameter. Both weirs have been omitted from the model due to drowning out at any significant flow.

4.2.13 A wooden footbridge was identified approximately 615m upstream of the downstream boundary. It has a 5m wide, thick deck. This footbridge was omitted from the model as there were no abutments in the channel.

Roughness

4.2.14 Roughness values utilised are in line with the recommended values stated within Chow, 1959[5].

4.2.15 The 2D domain roughness values have been informed by the land use classifications within the current Ordnance Survey (OS) Mastermap data together with information derived from aerial and site visit photography for specific features.

4.2.16 In some locations the OS Mastermap data has been modified to suit the cell size of the hydraulic model, to ensure that key features such as woodland, roads and the channel itself are represented.

4.3 Hydraulic model build – Proposed Scheme

4.3.1 The Proposed Scheme model has been edited from the baseline to include the following:

Viaduct piers

4.3.2 The proposed Pyford Brook viaduct spans approximately 180m and will be supported by seven piers, spaced approximately 15-30m apart.

4.3.3 A deactivated code layer was used to represent the piers. The modelled dimensions of each pier constitute a deactivated area of the model of 28m^2 per pier, for a pier size of 14.5m x 2m (29m^2).

Topographic changes

4.3.4 The Proposed Scheme embankments (Pyford South embankment and Pyford North embankment) have been included using the relevant heights for embankment crest. The footprints of these embankments are based on the details shown in Maps CT-06-201 and CT-06-201-R1 in the Volume 2 Map Book.

4.3.5 The OS Mastermap layer was modified to correctly represent any changes to the roughness and planting associated with the Proposed Scheme.

Replacement floodplain storage areas

4.3.6 Although there are only localised changes between baseline and post-development, provision for replacement floodplain storage has been made based on the 1.0% + CC AEP levels, on a level for level, volume for volume basis. This has not been included within the hydraulic modelling.

[5] Chow, V.T (1959), *Open-channel hydraulics*, McGraw-Hill, New York

Channel realignments and diversions

4.3.7 No realignments or diversions of the river channel have been proposed.

Production of flood extents

4.3.8 Flood extents have been derived using the direct output options now available in TUFLOW to produce ASCII output for the maximum depth and height. This has then been converted into a polygon, and cleaned to remove all bow ties (where two polygons overlap) and any dry islands less than $48m^2$.

Modelling assumptions made

4.3.9 Existing LiDAR is assumed to be correct as no other information is available.

4.3.10 All elevation points were assumed to create a smooth gradient throughout the channel. Points were taken from the lowest cells in the LiDAR which was assumed to be the river bed level.

4.3.11 Culvert sizes have been assumed in a number of places within the model. Where a site visit to provide photos or measurements was not possible, they have been approximated based on LiDAR information. This provided road levels and ground levels, and the measured width of the top of structures from aerial photography.

4.4 Climate change

4.4.1 The climate change allowance for Pyford Brook is 50% based on the new climate change approach developed by the Environment Agency and published in February 2016.[6]

4.4.2 This climate change percentage considers the design life of the Proposed Scheme (120 years), the River Basin District (Humber) and the receptors within the existing Flood Map for Planning. Due to the presence of more vulnerable receptors (National Planning Policy Framework Table 2[7]), the upper end value for the longest duration was chosen.

4.4.3 The new climate change guidance recommends consideration of the H++ scenario[8]. While these percentages have not been explicitly assessed, the sensitivity for the 20% increase in flow on the 1.0% + CC AEP event is assumed to be representative of an event greater than the H++ scenario.

[6] Environment Agency, *Flood risk assessments: climate change allowances*, https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

[7] Gov.uk, Flood Zone and flood risk tables, https://www.gov.uk/guidance/flood-risk-and-coastal-change#flood-zone-and-flood-risk-tables

[8] Environment Agency, *Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/571572/LIT_5707.pdf

5 Model results

5.1.1 The model has been run for the 50%, 20%, 5.0%, 1.33%, 1.0%, 1.0%+CC, 0.5% and 0.1% AEPs. The 1.0%+CC simulation is based on a 50% increase in flows.

5.1.2 The water level difference has been mapped for 5.0% AEP and 1.0%+CC AEP. These flood maps are reported in Appendix A.

5.1.3 In all return periods modelled above the 5% AEP, impacts of 0-10mm are observed around the proposed Pyford Brook viaduct with a maximum impact between 10mm-50mm. There is no change to the flood extent.

5.1.4 Model results conclude that the current proposed design ensures a freeboard of a minimum of 1m to the rail track in a 0.1% AEP event and a minimum of 0.6m to the viaduct soffit in a 1.0%AEP + CC (50%) event for all scenarios.

6 Model Proving

6.1 Introduction

6.1.1 This section of the report presents the analysis of the model undertaken to ensure confidence in the stability of the model build, its response to input values and consistency with previous modelling.

6.2 Run performance

6.2.1 Model output has been assessed across all open channel and model structures to assess model stability and overall model performance.

6.2.2 Final cumulative mass balance error is within +/-1.0% for all return periods and blockage and sensitivity cases simulated.

6.3 Calibration and validation

6.3.1 There is no gauge situated within an appropriate distance of this location to provide calibration or validation data.

6.3.2 There is no additional anecdotal evidence available for any effective model validation exercise.

6.4 Verification

6.4.1 Model outputs have been compared with other readily available flood risk data such as Environment Agency Flood Maps for Planning.

6.4.2 Flood extents generated for this study are similar to the Environment Agency Flood Maps for Planning except for around both upstream structures; Wood End Lane and the Trent and Mersey Canal. In this location the modelled extent is much wider than the Environment Agency map because the Environment Agency Flood Zones do not pick up or represent these structures. However, this extent is consistent with the uFMfSW in this location.

6.5 Sensitivity analysis

6.5.1 Sensitivity scenarios were undertaken as below:

- increase in flow by 20% (compared to 1.0%AEP+CC Proposed Scheme);
- increase in roughness (channel, structures and floodplain) (Manning's n) by 20% (compared to 1.0%AEP+CC Proposed Scheme);
- decrease in roughness (channel, structures and floodplain) (Manning's n) by 20% (compared to 1.0%AEP+CC Proposed Scheme);
- increase in downstream boundary gradient by 20% (compared to 1.0%AEP+CC Proposed Scheme); and

- decrease in downstream boundary gradient by 20% (compared to 1.0%AEP+CC Proposed Scheme).

Roughness

6.5.2 The model is sensitive to increases in roughness with a 20% increase resulting in increases in peak water level of greater than 100mm in the section upstream of the Trent and Mersey Canal. This impact reduced to between 10-50mm downstream of the Trent and Mersey Canal aqueduct and continued to decrease towards the downstream extent. A negligible change in the flood extent is observed.

6.5.3 Decreasing the roughness by 20% results in a general decrease in peak water level throughout the model. A negligible decrease in the flood extent is observed.

Inflows

6.5.4 An increase in inflow of 20% results in a maximum increase of greater than 100mm at the section upstream of the Trent and Mersey Canal and an increase of 50-100mm at the proposed Pyford Brook viaduct. This reduces to an impact of 10-50mm directly downstream of the proposed Pyford Brook viaduct. A negligible change in the flood extent is observed.

Downstream boundary

6.5.5 There was no impact to the Proposed Scheme crossing when the downstream boundary was reduced and increased by 20%, with negligible impact of below 10mm observed at the downstream boundary. No impact is seen greater than 10m from the downstream extent.

Summary

6.5.6 The sensitivity analysis shows the model is moderately sensitive to changes in flows and roughness values at the proposed Pyford Brook viaduct. The changes in the downstream boundary gradient had no impact at the proposed Pyford Brook viaduct with negligible impact at the downstream boundary of the model.

6.5.7 Sensitivity tests conclude that the current proposed design ensures a freeboard of a minimum of 0.6m to the viaduct soffit in a 1.0%AEP+CC (50%) event for all scenarios.

6.6 Blockage analysis

6.6.1 One blockage scenario was assessed which modelled a 2% blockage at the proposed Pyford Brook viaduct.

6.6.2 This blockage scenario result was compared to the 0.1% AEP results for the Proposed Scheme model.

6.6.3 The viaduct blockage of 2% was represented for the proposed Pyford Brook viaduct by expanding the size of the pier standing nearest to the main channel by 2% of the length of the viaduct.

6.6.4 The results of the blockage scenario show a negligible impact to peak flood levels. Up to 10mm impact was observed around the southern abutment of the proposed Pyford Brook viaduct.

6.6.5 No other structures were blocked as both upstream structures; Wood End Lane and the Trent and Mersey Canal; would hold back more water upstream and present a positive impact at the proposed Pyford Brook viaduct.

6.6.6 Blockage tests conclude that the current proposed design ensures a freeboard of a minimum of 1m to the rail track in a 0.1% AEP event for all scenarios.

6.7 Run parameters

6.7.1 There is no deviation from default run parameters for all model runs.

6.7.2 The time step parameters used were 0.5 seconds for ESTRY and 1 second for the 2D model. This is the suggested approach for a grid size of 2m.

7 Limitations

7.1.1 Land access for new topographic survey was not possible, however Phase One survey was provided at the upstream extent of the model. In addition, all channels have been represented in 2D, meaning channel conveyance will not be fully represented in the model; however, this will lead to a conservative estimation of flood risk for the purposes of the EIA. On site observations have been used to reduce the number of assumptions, with some culvert dimensions having been estimated based upon ground levels and watercourse size, which may impact flood extent and level predictions if these were to change.

7.1.2 No survey data was available for the watercourse downstream of the Phase One model extent therefore this section of the model has been developed based on the LiDAR provided.

7.1.3 The extent of the model is limited downstream due to LiDAR availability. LiDAR was unavailable for the area towards the downstream extent where Pyford Brook runs towards the confluence with Ashby Sitch. Only 5m LiDAR was available in this area but it was unsuitable due to its poor accuracy.

7.1.4 Calibration has not been able to be carried out due to a lack of available data.

8 Conclusions and recommendations

8.1.1 The aim of developing a hydraulic model of Pyford Brook to simulate the baseline and Proposed Scheme scenarios and to determine the peak water levels and flows throughout the catchment has been met.

8.1.2 Increases in water level caused by the Proposed Scheme are around 10mm-50mm over a localised area close to the viaduct.

8.1.3 Blockage and sensitivity analyses have demonstrated that changes in key variables such as roughness, model inflows and downstream boundary location and gradient result in modelled water levels that remain below the critical freeboard requirements.

8.1.4 At detailed design stage, the hydraulic modelling of the watercourse should be revisited. Further topographic survey data of the channel should be collected and used to extend the Phase 1 model to cover the full modelled extent reported in this document. This will provide better representation of the channel conveyance processes and refine the model outputs, allowing the model to be used to: confirm flood risk from the Phase 2a scheme, confirm any in-combination effects with the Phase 1 scheme, and test any necessary flood risk mitigation measures within the model.

8.1.5 If preliminary results deem it necessary, this model should then be converted into a linked 1D-2D model.

9 References

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Appendix A: Flood level impact maps

1.1.1 The water level difference has been mapped for 5.0% AEP and 1.0%+CC AEP as described in Section 5, see Figures A-1 and A-2.

Figure A-1: Pyford Brook at Fradley Impact Map for 5% AEP (1 in 20 year)

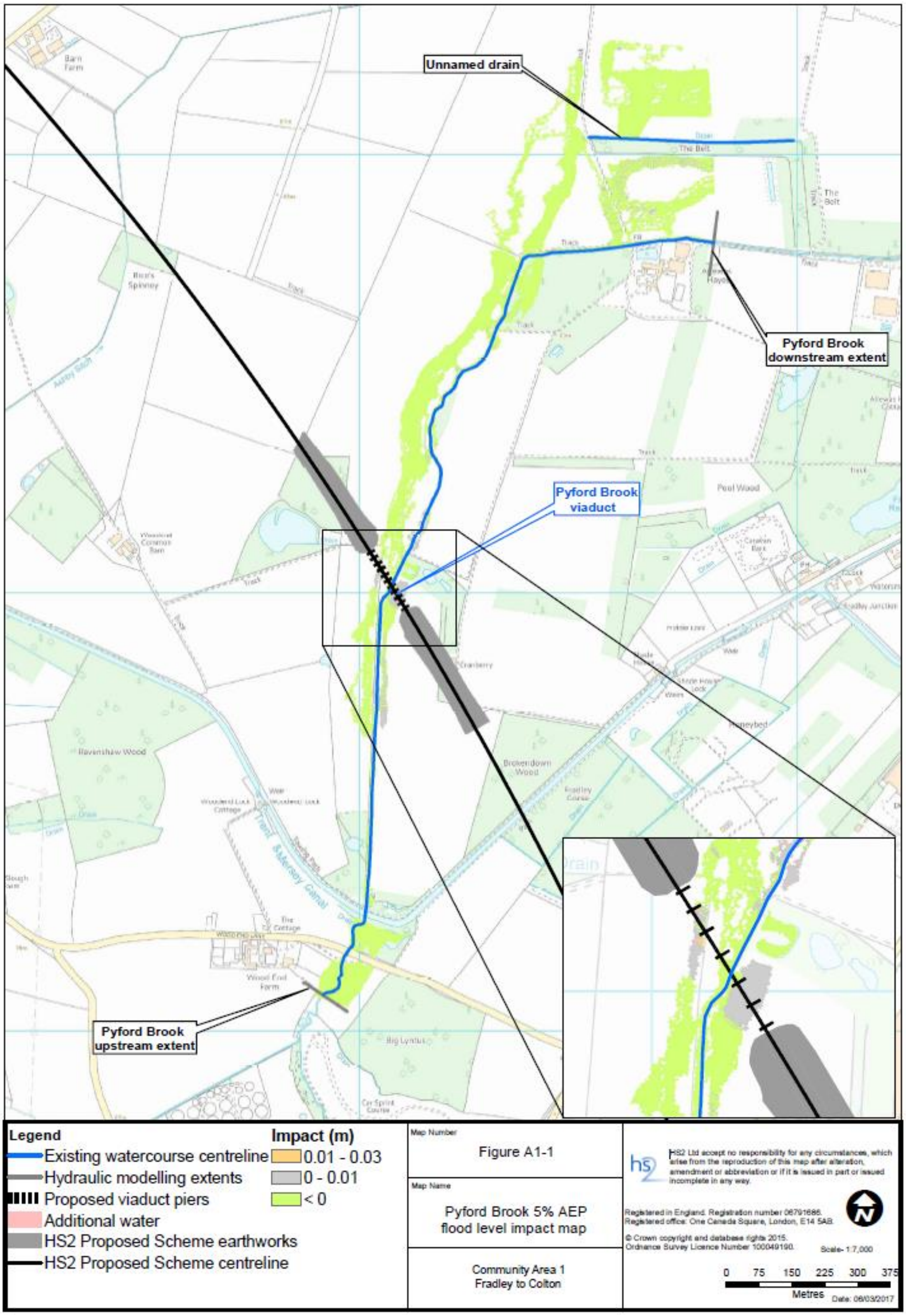
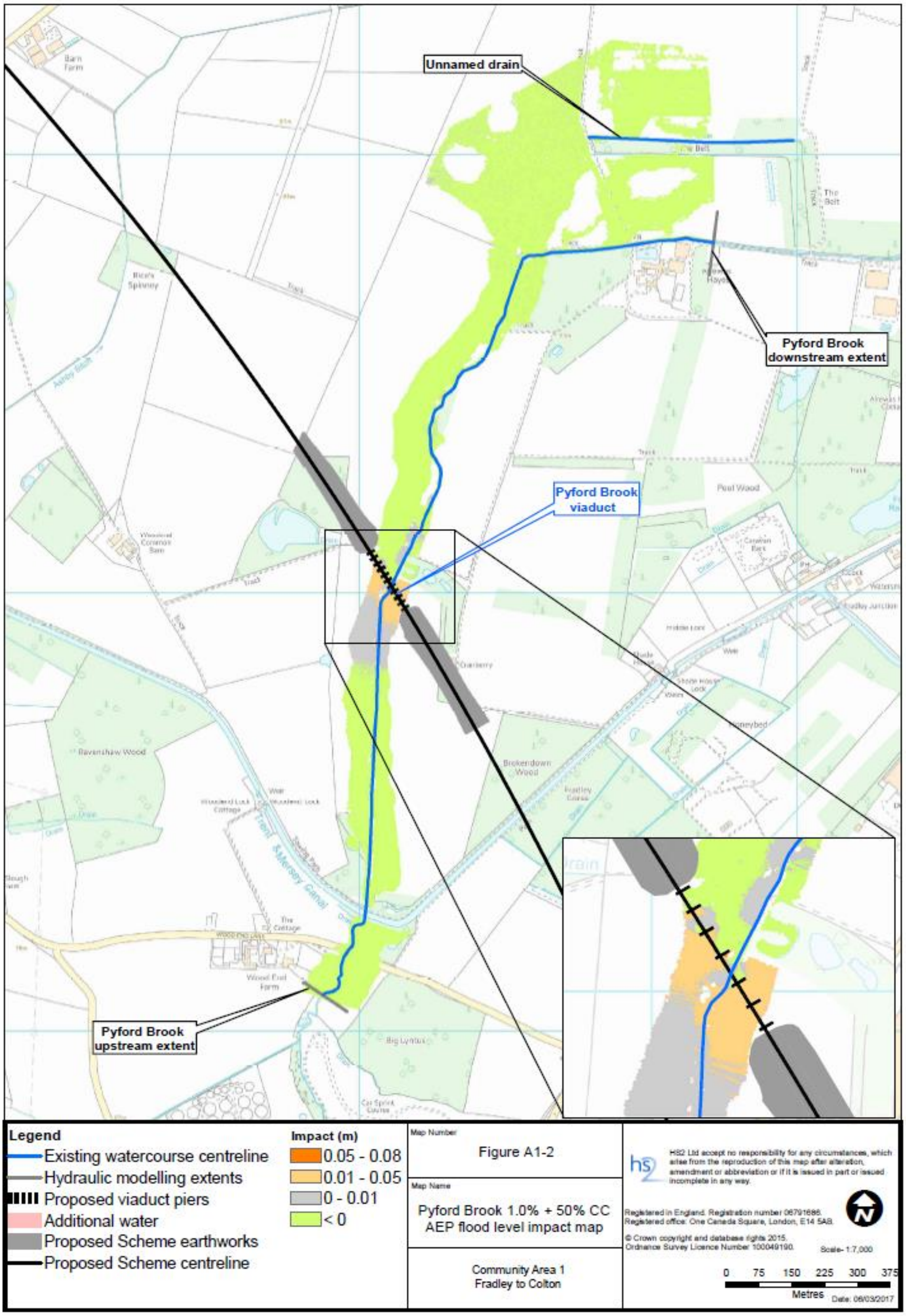


Figure A-2: Pyford Brook at Fradley Impact Map for 1% AEP + CC (1 in 100 year) plus 50% climate change allowance



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