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HS2

High Speed Rail (Crewe – Manchester) Environmental Statement

Volume 5: Appendix WR-006-00003

Water resources and flood risk

MA05: Risley to Bamfurlong

Hydraulic modelling report - Tributaries of Holcroft Lane Brook

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Department for Transport

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High Speed Two (HS2) Limited
Two Snowhill
Snow Hill Queensway
Birmingham B4 6GA

Telephone: 08081 434 434

General email enquiries: HS2enquiries@hs2.org.uk

Website: www.hs2.org.uk

A report prepared for High Speed Two (HS2) Limited:

ARUP+ ERM | FOSTER + PARTNERS | JACOBS
RAMBOLL | TYPSA | COSTAIN

MWJV
Mott MacDonald | WSP

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1 Introduction

1.1 Background

1.1.1 This appendix presents the results of the hydraulic modelling carried out for tributaries of Holcroft Lane Brook 2 to 4, in the Glaze Brook catchment. Tributaries of Holcroft Lane Brook 2 to 4 run through the Risley to Bamfurlong area (MA05).

1.1.2 The hydraulic modelling has been used to inform the flood risk assessment (Volume 5: Appendix WR-005-0MA05) for this community area.

1.1.3 The following hydraulic modelling reports are also relevant to this area:

- hydraulic modelling report – Small Brook (Volume 5: Appendix WR-006-00004);
- hydraulic modelling report – Carr Brook (Volume 5: Appendix WR-006-00005); and
- hydraulic modelling report – Hey Brook (Volume 5: Appendix WR-006-00006).

1.1.4 The water resources and flood risk assessments include both route-wide and community area specific appendices. The route-wide appendices comprise:

- a Water Framework Directive (WFD) compliance assessment (Volume 5: Appendix WR-001-00000); and
- a draft water resources and flood risk operation and maintenance plan (Volume 5: Appendix WR-007-00000).

1.1.5 For the Risley to Bamfurlong area the water resources assessment, Volume 5: Appendix WR-003-0MA05 should also be referred to.

1.1.6 Additional information is included in Background Information and Data (BID):

- Water resources assessment baseline data that are reported per community area (BID WR-004-0MA05)[1]; and
- Water Framework Directive compliance assessment baseline data for the Proposed Scheme (BID WR-002-00001)[2].

1.2 Aims

1.2.1 The aim of this study was to develop a hydraulic model of tributaries of Holcroft Lane Brook 2 and 4 at and in the vicinity of the Proposed Scheme crossings to simulate peak flood levels,

[1] High Speed Two Ltd (2022), High Speed Rail (Crewe – Manchester), *Background Information and Data, Water resources assessment baseline data,* BID WR-004-0MA05. Available online at: http://www.gov.uk/government/collections/hs2-phase-2b-crewe-manchester-environmental-statement.
[2] High Speed Two Ltd (2022), High Speed Rail (Crewe – Manchester), *Background Information and Data, Water Framework Directive compliance assessment baseline data,* BID WR-002-00001. Available online at: http://www.gov.uk/government/collections/hs2-phase-2b-crewe-manchester-environmental-statement.

with and without the Proposed Scheme. This report also aims to document the methods used, results, assumptions and limitations.

1.2.2 The outputs from the study have been used to inform the flood risk assessment for the Risley to Bamfurlong area (MA05), that is reported in Volume 5 of the Environmental Statement. The hydraulic model has also informed the preliminary design of the Proposed Scheme, with the specific objectives of ensuring that the design of hydraulic structures (for example: viaducts, bridges and culverts) takes account of flood risk issues, as detailed in the Environmental Impact Assessment Scope and Methodology Report (SMR): Technical Note: Flood risk (see Volume 5: Appendix CT-001-00001).

1.3 Objectives

1.3.1 The objectives of this study were to:

- develop an understanding of existing hydraulic conditions at the proposed watercourse crossings, including channel and floodplain characteristics, hydraulic structures and flow paths, through desk study and, where possible, by conducting a site visit;
- estimate peak flows, and hydrographs, at the Proposed Scheme crossing locations, associated with the following Annual Exceedance Probabilities (AEP): 5.0%, 1.0%, 1.0% + climate change (CC), and 0.1%; and
- develop a hydraulic model, using the information available at this stage, to estimate the flood levels associated with these peak flows along the study reach, both before and after construction of the Proposed Scheme.

1.4 Justification of approach

1.4.1 A risk-based approach has been adopted, whereby the level of modelling detail supporting the flood risk assessment at a specific site reflects the magnitude of the likely impacts of the Proposed Scheme on peak flood levels and the sensitivity of nearby receptors to flooding.

1.4.2 Although Tributary of Holcroft Lane Brook 2 is a main river, there is no Environment Agency flood zone[3] information available. Holcroft Lane Brook is a main river downstream of the Proposed Scheme crossing, where flood zone information is available. There are a number of local receptors located downstream of the Proposed Scheme crossings. Due to the small size of the catchment, a direct rainfall 2D hydraulic modelling approach has been adopted, with input hyetographs derived using Revitalised Flood Hydrograph 2 (ReFH2) software[4].

[3] Environment Agency (2021), *Flood Zone and flood risk tables*. Available online at: https://www.gov.uk/guidance/flood-risk-and-coastal-change#flood-zone-and-flood-risk-tables.

[4] WHS (2016), *Revitalised Flood Hydrograph Model ReFH2: Technical Guidance.*

1.5 Scope

1.5.1 The scope of the study was to undertake hydraulic modelling to enable assessment of the impact of the Proposed Scheme on the local environment.

1.5.2 This report focuses on an approximately 1km reach of Tributary of Holcroft Lane Brook 2 and 3 and an approximately 3.5km reach of Tributary of Holcroft Lane Brook 4, extending upstream and downstream of the Proposed Scheme crossings. The proposed crossings comprise bridges over the realignments of tributaries of Holcroft Lane Brook 2 to 4 for the Proposed Scheme. A description of the location and type of scheme is provided in Section 2.

1.5.3 The scope of the report includes:

- discussion of all relevant datasets, in terms of their quality and gaps;
- details of the hydrological analysis undertaken, the approach used and the calculation steps;
- details of how the hydrological analysis has been integrated with the hydraulic modelling;
- identification and justification of the hydraulic modelling methodology selected; and
- a description of the hydraulic modelling parameters, assumptions, limitations and uncertainty.

2 Qualitative description of flood response

2.1 Sources of information

2.1.1 The following sources of information were obtained from the Environment Agency:

- flood map for planning (rivers and sea)[5];
- risk of flooding from surface water (RoFSW)[6] map; and
- flood defence asset information.

2.1.2 Additional information from the Lead Local Flood Authority (LLFA) and publicly available sources included:

- Warrington Borough Preliminary Flood Risk Assessment (2017)[7];
- Warrington Strategic Flood Risk Assessment (2008)[8]; and
- Warrington Borough Council Local Flood Risk Management Strategy (2017)[9].

2.2 Description of the study area

Study area

2.2.1 The Proposed Scheme crossings of tributaries of Holcroft Lane Brook 2 to 4 are located upstream of the confluence of Holcroft Lane Brook with Glaze Brook.

2.2.2 Figure 1 shows the study area and the Environment Agency risk of flooding from surface water maps[6]. The upstream boundary is located next to Her Majesty's Prison (HMP) Risley on Warrington Road. The downstream boundary of the model is located immediately upstream of the watercourse crossing at Holcroft Lane.

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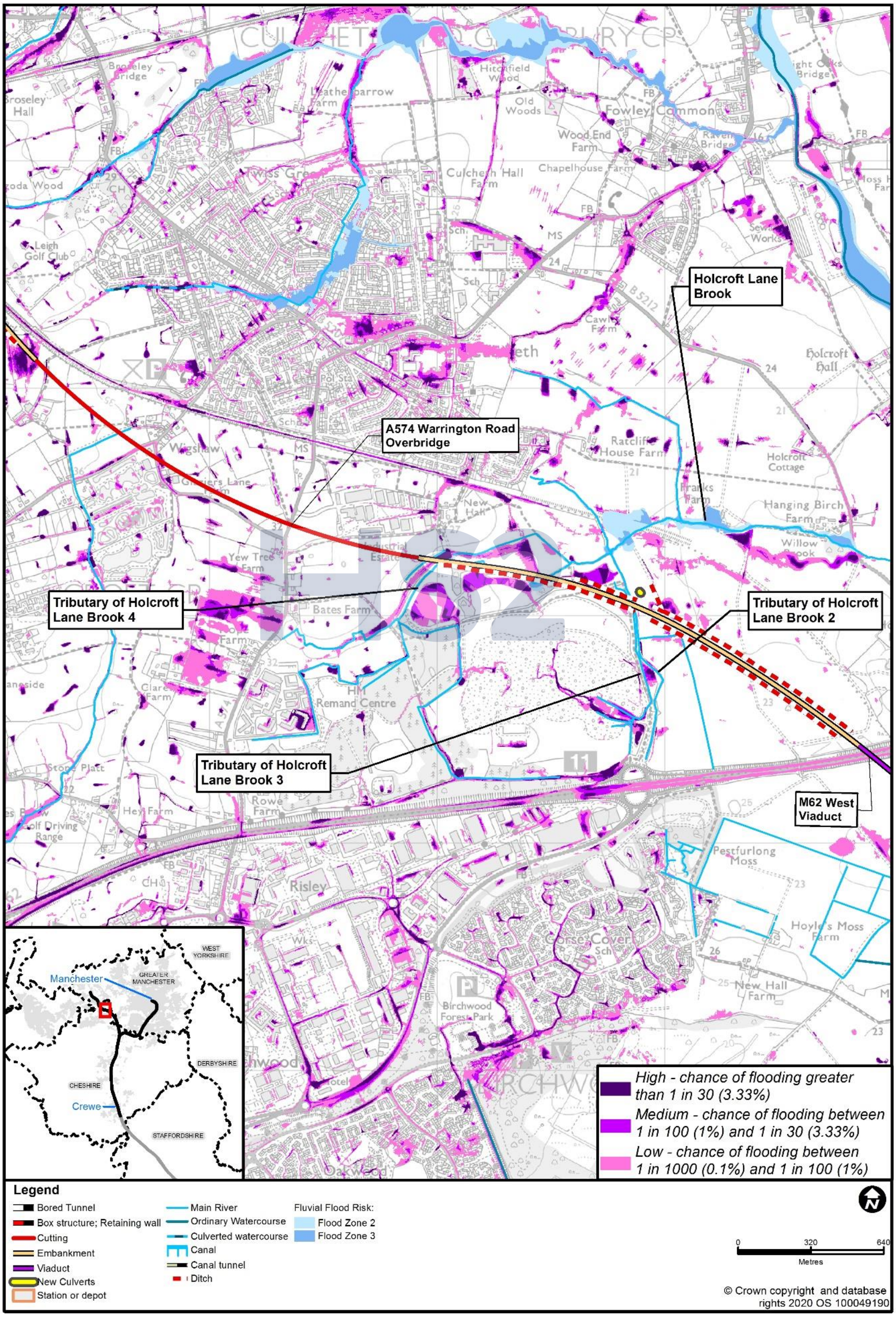
[5] Environment Agency (2021), *Flood map for planning*. Available online at: https://flood-map-for-planning.service.gov.uk.
[6] Environment Agency (2021), *The risk of flooding from surface water*. Available online at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map.
[7] Warrington Borough Council (2017), *Warrington Preliminary Flood Risk Assessment.* Available online at: https://www.warrington.gov.uk/sites/default/files/2019-10/preliminary_flood_risk_assessment_pfra_2017_-_2023.pdf.
[8] JBA Consulting (2008), *Warrington Strategic Flood Risk Assessment.* Available online at: https://www.warrington.gov.uk/sites/default/files/2019-08/warrington_strategic_flood_risk_assessment_i_2008.pdf.
[9] Warrington Borough Council (2017), *Warrington Local Flood Risk Management Strategy.* Available online at: https://www.warrington.gov.uk/sites/default/files/2019-10/local_flood_risk_management_strategy_2017_v7_af_approved.pdf.

Figure 1: Study area and Environment Agency Flood Zones and RoFSW (0.1% AEP) at tributaries of Holcroft Lane Brook 2 and 4



2.2.3 The primary hydraulic control on both Tributary of Holcroft Lane Brook 2 to 4 is the existing road crossing at Holcroft Lane. Flood levels in the lower reaches of Tributary of Holcroft Lane Brook 2 to 4 are unlikely to be influenced by backwater effects from Glaze Brook, that is located approximately 2km downstream of the Proposed Scheme crossings, and at an elevation at least 5m lower.

Hydrological description

2.2.4 Tributaries of Holcroft Lane Brook 2 and 3 originate north of the M62 and Tributary of Holcroft Lane Brook 4 originates near Warrington Road and Silver Lane. The catchment areas for the Holcroft Lane Brook are as follows: 0.94km^2 for Tributary of Holcroft Lane Brook 4, 0.88km^2 for Tributary of Holcroft Lane Brook 2, and 0.05km^2 for Tributary of Holcroft Lane Brook 3. The catchments are shown in Figure 2.

2.2.5 There are no gauging stations present within the catchments[10].

2.2.6 Standard annual average rainfall for the catchment at the model downstream boundary is 855mm[10].

Proposed Scheme

2.2.7 The route of the Proposed Scheme crosses Tributary of Holcroft Lane Brook 2 and Tributary of Holcroft Lane Brook 4 with new culvert crossings beneath the Proposed Scheme, north of the M62. Further detail on the Proposed Scheme can be found in the Volume 2, MA05 Map Books: maps CT-06-327 and CT-06-328.

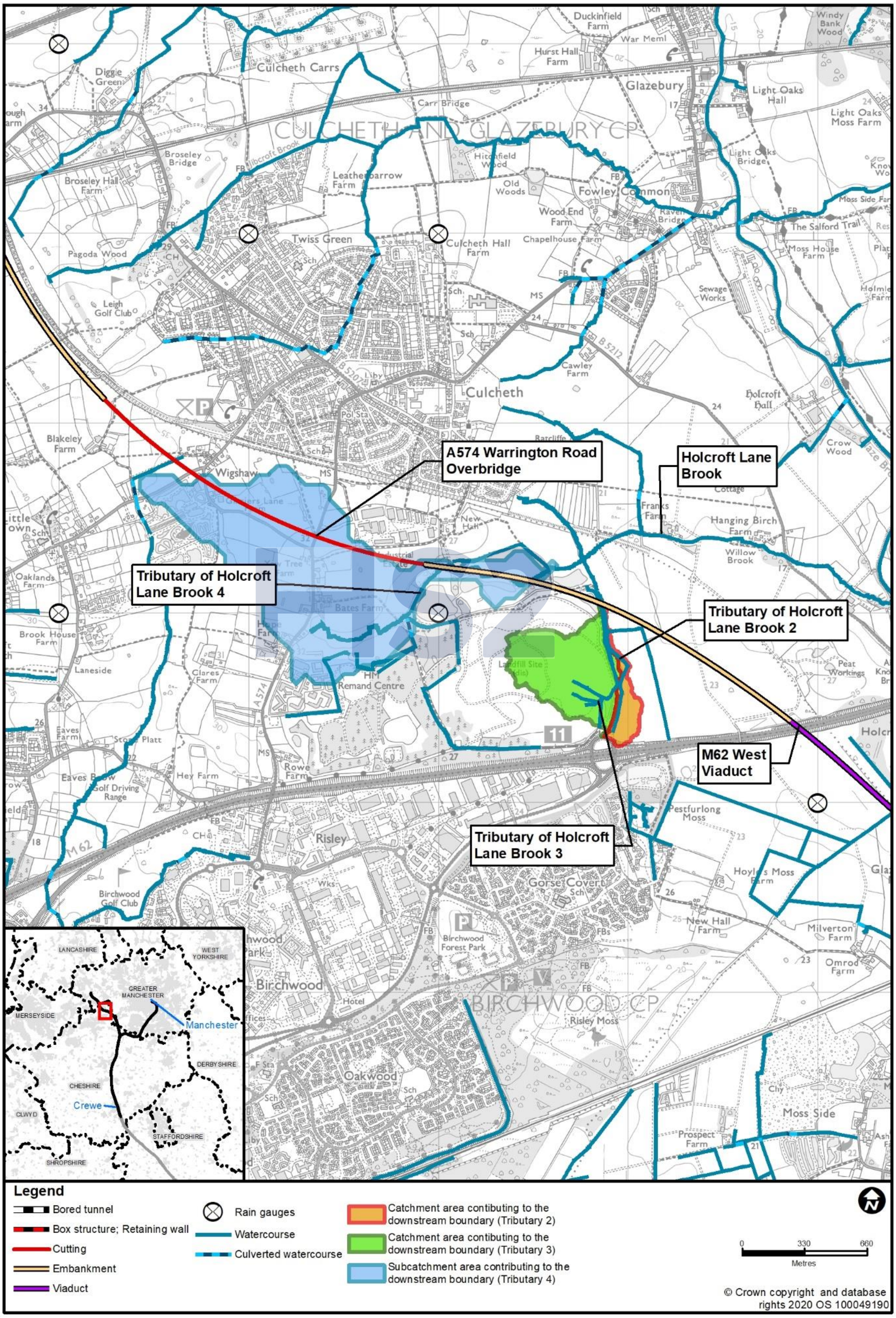
Features of note

2.2.8 From inspection of the Light Detection And Ranging (LiDAR) data, Tributary of Holcroft Lane Brook 2 appears to have been engineered in the vicinity of the Proposed Scheme crossing.

2.2.9 There is a higher-level drain immediately west of Tributary of Holcroft Lane Brook 2 that collects landfill runoff and discharges into attenuation ponds prior to discharging into Tributary of Holcroft Lane Brook 2.

[10] Centre for Ecology and Hydrology (2021), *Flood estimation handbook web service.* Available online at: http://fehweb.ceh.ac.uk.

Figure 2: Holcroft Lane Brook catchment area



2.3 Existing understanding of flood risk

Flood mechanisms

2.3.1 The Environment Agency flood zones[3] indicate that Holcroft Lane Brook runs mostly in-bank downstream of the Proposed Scheme crossing, as shown in Figure 1. However, the RoFSW maps show flooding diverging from the watercourse alignment (just upstream of Holcroft Lane) suggesting that this watercourse was realigned in the past. Based on the hydraulic modelling undertaken for the baseline 1.0% and 0.1% AEP events, the floodplains of tributaries of Holcroft Lane Brook 2 and 4 are not confined to the watercourse.

2.3.2 Available information does not indicate the presence of any flood defence assets within the model extent.

Analysis of historical flooding

2.3.3 No information on historical flood incidents has been identified from the Strategic Flood Risk Assessment (SFRA)[8] and Preliminary Flood Risk Assessment (PFRA)[7]. No Section 19 flood investigation reports[11] have been published for this area.

Availability of existing hydraulic models

2.3.4 Available information, that includes information from the Environment Agency, does not indicate the existence of hydraulic models for Tributary of Holcroft Lane Brook 2 to 4. However, there is a 1D model of Holcroft Lane Brook. The upstream channel cross section in this model is located immediately downstream of the confluence of tributaries of Holcroft Lane Brook 2 to 4.

2.4 Site visit

2.4.1 At this stage no site survey or site visit was undertaken to inform the proposed hydraulic analysis. When the hydraulic model is updated at the detailed design stage, in accordance with the HS2 Ltd requirements, a site visit will be undertaken by a hydraulic modeller to ensure a site-specific topographic survey specification can be developed.

[11] Section 19 of the Flood and Water Management Act 2010 sets out the requirement that on becoming aware of a flood in its area, a LLFA must investigate and report on which risk management authorities have relevant flood risk management functions and whether each authority has exercised those functions in response to the flood.

3 Model approach and justification

3.1 Model conceptualisation

3.1.1 The channel cross sections present in the Environment Agency 1D hydraulic model of Holcroft Lane Brook do not cover the study area of tributaries of Holcroft Lane Brook 2 to 4 and could therefore not be used in modelling the Proposed Scheme crossings. A 2D only hydraulic modelling approach was chosen for tributaries of Holcroft Lane Brook 2 and 4 study area as no 1D channel survey data were available.

3.1.2 1D channel survey cross sections from the 1D model on Holcroft Lane Brook have been compared against the LiDAR data captured for the Proposed Scheme. The two datasets were similar and therefore the LiDAR data were used for the development of this 2D model.

3.1.3 The 2D model domain has been extended sufficiently upstream and downstream to ensure the catchments of tributaries of Holcroft Lane Brook 2 and 4 are captured, and to ensure that any effects caused by the model boundaries do not affect water levels in the area of the Proposed Scheme.

3.1.4 High resolution 0.2m to 1m LiDAR data have been used to define the channel and to take account of the watercourse capacity and conveyance in the 2D model domain. In the absence of 1D survey data for the channel, this approach is considered to be sufficiently conservative for this stage of the design as the modelled channel has lower capacity than the actual channel. This leads to an underestimate of peak flows at the crossing but higher modelled peak water levels, as well as an overestimation of out of bank flows. The latter leading to a more conservative assessment of replacement flood storage requirements.

3.2 Software

3.2.1 Infoworks Integrated Catchment Modelling (ICM) (version 4.0.3.8010) has been used to apply the 2D modelling methodology. This software is in line with standard practice to use the latest available build at the time modelling commenced, while Infoworks ICM is industry standard software.

3.3 Topographic survey

3.3.1 No additional topographic survey were undertaken for this study but will be required during design development, to inform detailed design.

3.4 Input data

3.4.1 The elevation data for the study area was produced using 0.2m grid LiDAR Digital Terrain Model flown specifically for HS2 Ltd and covers 500m either side of the route. Where required, additional 1m grid LiDAR data provided by the Environment Agency were used. The data were used in areas further away from the Proposed Scheme crossings to provide full coverage of the 2D model extent.

4 Technical method and implementation

4.1 Hydrological assessment

4.1.1 No flow records are available for tributaries of Holcroft Lane Brook 2 and 4. Given the small catchment sizes at the Proposed Scheme crossings (0.94km^2 for Tributary of Holcroft Lane Brook 4 and 0.88km^2 for Tributary of Holcroft Lane Brook 2), a surface water modelling approach has been adopted. This uses direct net rainfall applied to the rural 2D domain (the 2D domain covers an area larger than the catchment). Resulting surface runoff is routed towards the downstream model boundary. The large landfill area to the south of the Proposed Scheme is likely to be capped with low permeability clay. Therefore, a fixed runoff coefficient of 1 on applied rainfall, has been assumed as a conservative approach. A runoff coefficient of 0.8 has been used for the rest of the 2D domain due to the clay nature of the soils within it.

4.1.2 The Flood Estimation Handbook (FEH)[12] ReFH2 rainfall hyetographs corresponding to a summer profile resulted in excessive estimates, particularly in the urbanised areas. Therefore, for this assessment the winter profile has been used. ReFH2 uses the recently updated FEH[13] rainfall database and parameters[13].

4.1.3 A hydrological verification has been undertaken by estimating catchment hydrology ReFH2 peak flow estimates at the Proposed Scheme crossings. This verification has been undertaken to check that the surface water modelled peak flows are similar, or greater, than the ReFH2 flow estimates. ReFH2 flow calculations are based on relevant catchment descriptors, that were obtained from the Flood Estimation Handbook (FEH) Web Service database[10].

4.1.4 Table 1 and Table 2 show the peak flows derived from the surface water modelling with Infoworks ICM at the proposed crossings and their comparison with the ReFH2 flow estimates.

Table 1: Peak flows at Tributary of Holcroft Lane Brook 4 crossing

AEP	Return period	Peak flow (m^3/s) Modelled	Peak flow (m^3/s) ReFH2
5.0%	20 year	0.88	0.67
1.0%	100 year	1.35	1.02
1.0% + CC	100 year + CC	2.03	1.43
0.1%	1000 year	2.55	1.79

[12] Kjeldsen.T.R, (2007), *Flood Estimation Handbook (FEH) Supplementary Report No. 1. The revitalised FSR/FEH rainfall-runoff method*. Centre for Ecology and Hydrology, Wallingford.

[13] WHS (2016), *Revitalised Flood Hydrograph Model ReFH2: Technical Guidance.*

Table 2: Peak flows at Tributary of Holcroft Lane Brook 2 and Tributary of Holcroft Lane Brook 3 crossing

AEP	Return period	Peak flow (m^3/s) Modelled	Peak flow (m^3/s) ReFH2
5.0%	20 year	0.27	0.26
1.0%	100 year	0.43	0.40
1.0% + CC	100 year + CC	0.58	0.57
0.1%	1000 year	1.02	0.74

4.1.5 Tributaries of Holcroft Lane Brook 2 and 3 are close together and therefore flows from these catchments have been combined (as shown in Table 2). Modelled flows for all tributaries are higher than the ReFH2 peak flows. It is concluded that the adopted surface modelling approach is more conservative than the estimates from the ReFH2. As this assessment is precautionary, further hydrological assessment will be undertaken during design development to improve the accuracy of the peak flow estimate for tributaries of Holcroft Lane Brook 2 to 4.

4.2 Hydraulic model build - baseline model

4.2.1 Figure 3 shows the existing and proposed model schematic.

1D representation

4.2.2 1D elements were not required for this hydraulic model.

2D representation

4.2.3 The cell size of the model was set as 2m. Element size and alignment for the 2D model mesh were optimised to ensure appropriate representation of the flow pathways whilst maintaining reasonable run times.

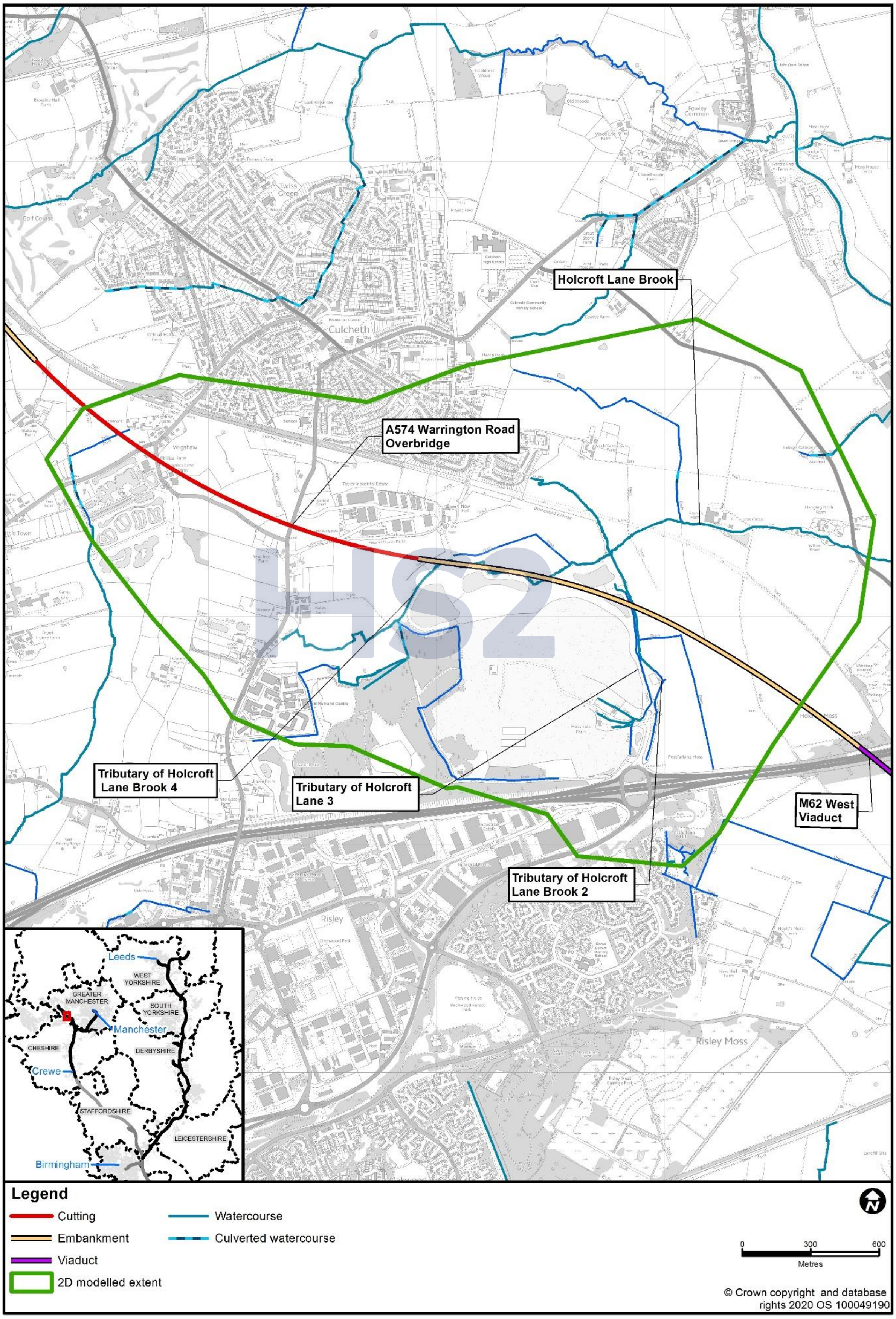
Inflow boundaries

4.2.4 There are no inflow boundaries in the model as direct rainfall has been applied over the 2D domain.

Downstream boundary

4.2.5 Unrestricted flow out of the 2D domain has been set based on inspection of the LiDAR and mapping along the 2D domain boundary, that indicate flood waters cannot backup and impact on the zone of influence. A sensitivity test has been carried out on the downstream boundary of the model.

Figure 3: Model schematic



Key structures

4.2.6 Existing minor structures within the watercourses have not been represented in the hydraulic model as these features are likely to be drowned out in low order events and will therefore not impact peak flood levels.

4.2.7 The only above ground feature that could impact on the flow paths within the 2D domain is the B5212 Holcroft Lane crossing. This structure is incorporated into the LiDAR data, and therefore, it is included in the 2D model.

Roughness

4.2.8 Roughness is represented by Manning's n, selected based on Ordnance Survey (OS) Mastermap data and aerial photography in line with the recommended values stated within Chow (1959)[14].

4.3 Hydraulic model build – Proposed Scheme

4.3.1 The Proposed Scheme model has been edited from the baseline to include the following design elements.

Underbridges

4.3.2 The Proposed Scheme embankment has been modelled as a raised 2D impermeable wall along the Proposed Scheme footprint to ensure any potential it has for impeding overland flows are understood.

4.3.3 At the crossing locations, an opening in the Proposed Scheme embankment wall was made. The modelling of the crossings as open areas, instead of as culverts, is considered acceptable as the crossings are high composite structures (no surcharge conditions) that allow footway and/or vehicular access.

4.3.4 The proposed underbridges at the Proposed Scheme crossings are shown in Table 3.

Table 3: Key structures present within the modelled extent of tributaries of Holcroft Lane Brook 2 and 4

Structure reference	Structure description	Modelling representation and justification
Tributary of Holcroft Lane Brook 2 and 3 Proposed Scheme crossing	6m wide and 6.1m high structure with adjacent vehicular access	Modelled as a 6m wide gap in the impermeable wall representing the Proposed Scheme embankment
Tributary of Holcroft Lane Brook 4 Proposed Scheme crossing	5m wide by 3.8m high structure with adjacent footway/cycleway access	Modelled as a 5m wide gap in the impermeable wall representing the Proposed Scheme embankment

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

Topographic changes

4.3.5 The Proposed Scheme embankment has been modelled as a high impermeable wall that follows the toe of the embankment of the Proposed Scheme based on the details shown in the Volume 2, MA05 Map Books: maps CT-06-327 and CT-06-328.

Channel realignments and diversions

4.3.6 Approximately 600m of Tributary of Holcroft Lane Brook 4 falls into the footprint of the Proposed Scheme. It is proposed to remove this 600m section of Tributary of Holcroft Lane Brook 4 and realign the watercourse to cross the Proposed Scheme through a culvert and discharge into the realigned Holcroft Lane Brook. The realigned Holcroft Lane Brook downstream of the Proposed Scheme crossing will be approximately 685m in length. It will have a widened channel profile compared to the existing to provide additional replacement floodplain storage on a volume for volume basis as a mitigation measure to ensure no increase in flood risk. The design of this mitigation measure will be further developed at the detailed design stage. The realignments have not been included in the hydraulic modelling.

4.3.7 Only a localised realignment is proposed by the outlet of the Proposed Scheme crossing of Tributary of Holcroft Lane Brook 2 to ensure the channel crosses at a ninety-degree angle to the Proposed Scheme alignment.

Production of flood extents

4.3.8 Flood extents have been derived using the direct output option available in Infoworks ICM, producing maximum flood depth and peak water level. The outputs have undergone a Proposed Scheme minus baseline calculation. The resulting layer was converted to polygons and cleaned to remove all bow ties (where two polygons overlap) and any dry islands that are less than $50m^2$. The differences were mapped to indicate the potential impacts of the Proposed Scheme.

Modelling assumptions made

4.3.9 LiDAR described in Section 3.1 is assumed to be correct.

4.3.10 A 2D modelling approach is assumed to be sufficient for estimating the 5.0%, 1.0% and 0.1% AEP events.

4.3.11 Existing minor structures are assumed to be drowned out in large flood events (5.0%, 1.0% and 0.1% AEP events) and therefore will not impact on the hydraulics of the return periods assessed.

4.3.12 It has been assumed the landfill area to the south of the Proposed Scheme is capped with clay and therefore on a precautionary basis it has been modelled as 100% impermeable.

4.3.13 The dimensions of key structures (such as the existing crossing of Holcroft Lane) are not based on visual inspection or survey, however, they are considered reasonable when compared to the channel cross section estimated from LiDAR and aerial photography.

4.4 Climate change

4.4.1 The climate change allowance for the direct rainfall for the tributaries of Holcroft Lane Brook 2 and 4 is a 40% increase in peak rainfall intensity as the catchment is less than 5km^2 in size.

4.4.2 The H++ allowance for tributaries of Holcroft Lane Brook 2 and 4 is a 60% increase in peak rainfall intensity, and this has been used for the purpose of sensitivity analysis.

5 Model results

5.1.1 The model has been run for the 5.0%, 1.0%, 1.0%+CC, and 0.1% AEPs. The 1.0% AEP + CC simulation is based on a 40% increase in peak rainfall intensity.

5.1.2 The Proposed Scheme has been run for the 1.0% AEP + CC and the 0.1% AEP. The water level difference has been mapped for 5.0% AEP and 1.0% AEP + CC. These flood maps are included in Annex A.

5.1.3 The modelled flood extents with and without the Proposed Scheme for the 5.0% AEP and the 1.0% AEP + CC events are presented in the Volume 5, Water resources and flood risk Map Book: map WR-05-315 and WR-06-315 respectively.

5.1.4 The modelled impact of the Proposed Scheme, without mitigation, on peak flood levels indicates the potential for:

- an approximate increase in peak flood levels of 200mm from the crossing to 400m upstream (see Annex A, Figure A 2 location A) at Tributary of Holcroft Lane Brook 2;
- decreases in peak flood level of approximately 300mm 140m west of Tributary of Holcroft Lane Brook 2, adjacent to the Proposed Scheme embankment (see Annex A, Figure A 2 location B);
- increases in peak flood level of approximately 700mm, 50m east of Tributary of Holcroft Lane Brook 2, adjacent to an existing pond (see Annex A, Figure A 2 location C). The increase in peak water level at location C is localised and limited to the area between Tributary of Holcroft Lane Brook 2 and the Proposed Scheme embankment; and
- an approximate increase in peak water level of 160mm (see Annex A, Figure A 2 location D) at Tributary of Holcroft Lane Brook 4, immediately adjacent to the Proposed Scheme.

5.1.5 The model results indicate a decrease in peak flood level greater than 100mm immediately downstream of the Proposed Scheme and east of Tributary of Holcroft Lane Brook 2 (see Annex A, Figure A 2 location E).

5.1.6 Model results indicate that the current proposed design achieves the freeboard requirements for both the top of rail level and HS2 watercourse crossing soffits.

6 Model proving

6.1 Run performance

6.1.1 The time step used was 0.5 seconds. This is the suggested approach for a grid size of 2m. Final cumulative mass balance error is within +/-1.0% for all model runs undertaken.

6.2 Calibration and verification

6.2.1 There is no river gauge situated within an appropriate distance of this location to provide calibration or verification data.

6.3 Validation

6.3.1 Flood extents generated for the baseline model are similar to those shown on the Environment Agency RoFSW for the 1.0% AEP and 0.1% AEP events.

6.4 Sensitivity analysis

6.4.1 Analysis was undertaken to assess the sensitivity of the 1.0% AEP + CC Proposed Scheme model outputs to the following scenarios:

- use of H++ climate change scenario of 60%;
- increase in roughness (channel, structures and floodplain) (Manning's n) by 20%; and
- decrease in roughness (channel, structures and floodplain) (Manning's n) by 20%.

6.4.2 No sensitivity tests have been undertaken for the downstream boundary normal depth slope at this stage, as the model is only 2D and has been extended sufficiently downstream to ensure that there is no effect at the Proposed Scheme crossing. These tests will be undertaken once the models are fully converted to 1D-2D at the detailed design stage.

6.4.3 Modelling demonstrates there are no key structures influencing flood levels and flood extents upstream and downstream of the Proposed Scheme.

6.4.4 Sensitivity tests indicate that the Proposed Scheme hydraulic design is not unduly sensitive to changes in key input parameters. In all cases, changes in peak water levels are less than 100mm.

6.5 Blockage analysis

6.5.1 Blockage of 50% at the Proposed Scheme crossings was simulated by reducing the widths of the crossings by half. The blockage scenario results were compared to the 0.1% AEP results for the Proposed Scheme model. This comparison indicated that there was an increase in peak water level of 140mm and 570mm at the crossings of the Tributary of Holcroft Lane Brook 2 and Tributary of Holcroft Lane Brook 4 respectively.

6.5.2 The blockage test confirms that the Proposed Scheme design ensures a freeboard of a minimum of 1m to the track level in a 0.1% AEP event. There is an approximate freeboard of 5m and 3.9m at the Tributary of Holcroft Lane Brook 2 and Tributary of Holcroft Lane Brook 4 crossings respectively (the crossings have been designed for access rather than flow).

6.6 Run parameters

6.6.1 There is no deviation from default run parameters recommended in Infoworks ICM, for all model runs.

7 Limitations

7.1.1 Land access for a new topographic survey was not possible and so the model was built using available LiDAR information supplemented by Mastermap and OS map data.

7.1.2 All channels have been represented in 2D as the 0.2m LiDAR data captures the channel width but not its full depth. Channel conveyance is therefore not fully represented in the model. This is likely to have resulted in a conservatively high estimate of peak flood levels.

7.1.3 Calibration was not possible due to a lack of available historical data.

7.1.4 The hydraulic model applies high runoff coefficients (between 80% and 100%) to simulate flows similar to the ReFH2 peak flow estimates, as the channel capacity is not accurately represented in the 2D modelling. A more detailed hydrological assessment should be undertaken in the detailed design stage.

8 Conclusions and recommendations

8.1.1 The model results indicate that there will be an increase in peak flood level of up to 700mm in the immediate vicinity of the Proposed Scheme, without mitigation.

8.1.2 The modelling has shown localised increases and decreases in peak flood levels at the embankment of Proposed Scheme that are not associated with the Holcroft Lane Brook tributaries. This is a result of the direct rainfall modelling approach, where small flow paths defined in the topography result in surface runoff that can be interrupted by the Proposed Scheme. These flow paths that are not associated with a watercourse will be addressed using an open ditch at the foot of the Proposed Scheme embankment, which will discharge into the Tributary of Holcroft Lane Brook 2.

8.1.3 Blockage and sensitivity analyses indicate that the results are not unduly sensitive to changes in key input variables.

8.1.4 The model results indicate that the Proposed Scheme achieves the freeboard requirements for both the top of rail level and the Proposed Scheme watercourse crossing soffits.

8.1.5 At detailed design stage, the hydraulic modelling of the watercourse should be revisited. Topographic survey data of the channel and structures should be collected and used to extend the model to cover the full modelled extent reported in this document. The updated model should be used to develop the detailed hydraulic design of the Proposed Scheme with a view to reducing impacts in peak flood levels in so far as reasonably practicable. The model should also be used to verify the magnitude of residual impacts (if any) of the final scheme design, for consenting purposes.

Annex A: Flood level impact maps

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

Figure A 1: Tributaries of Holcroft Lane Brook 2, 3 and 4 impact map for 5.0% AEP (1 in 20 year)

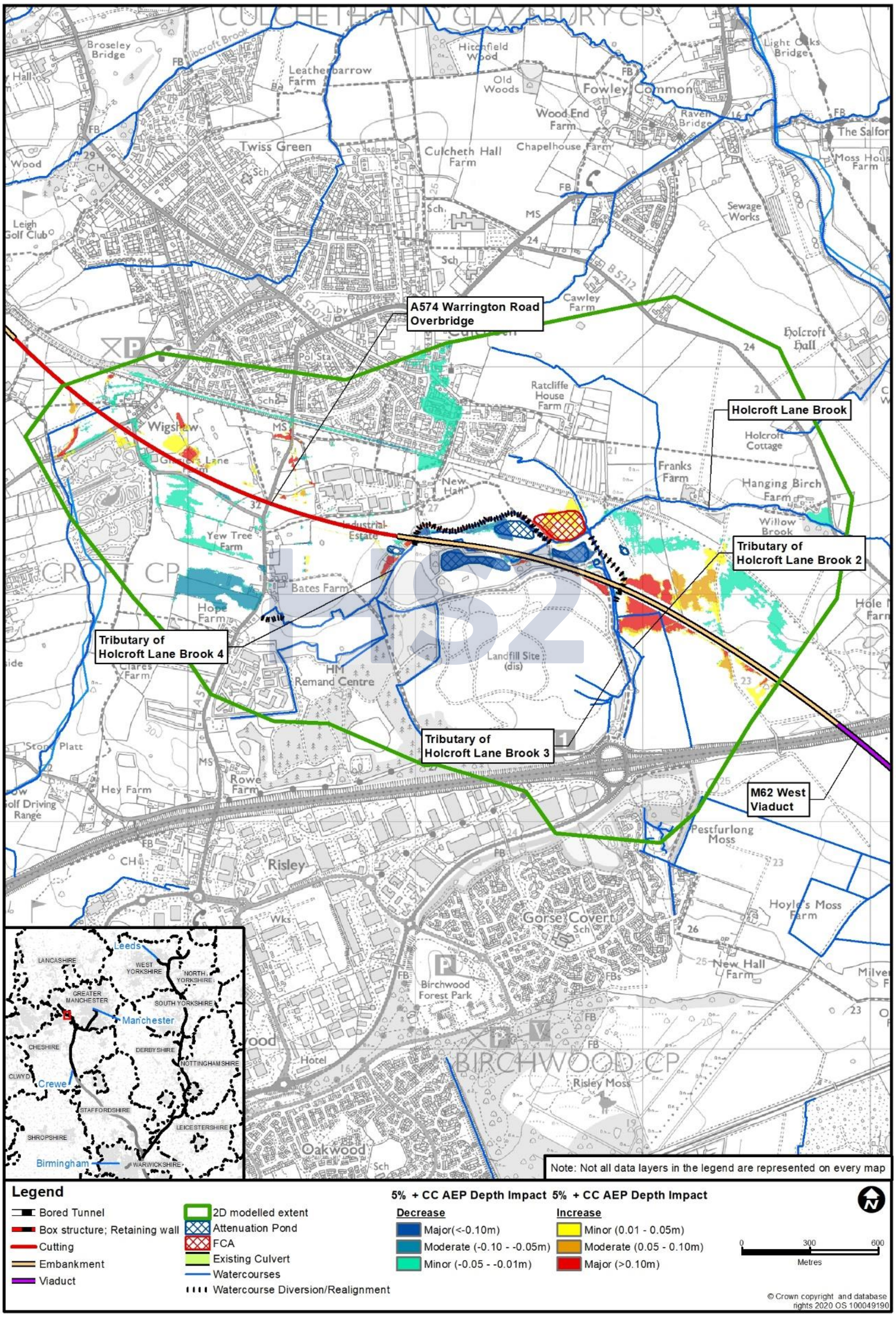
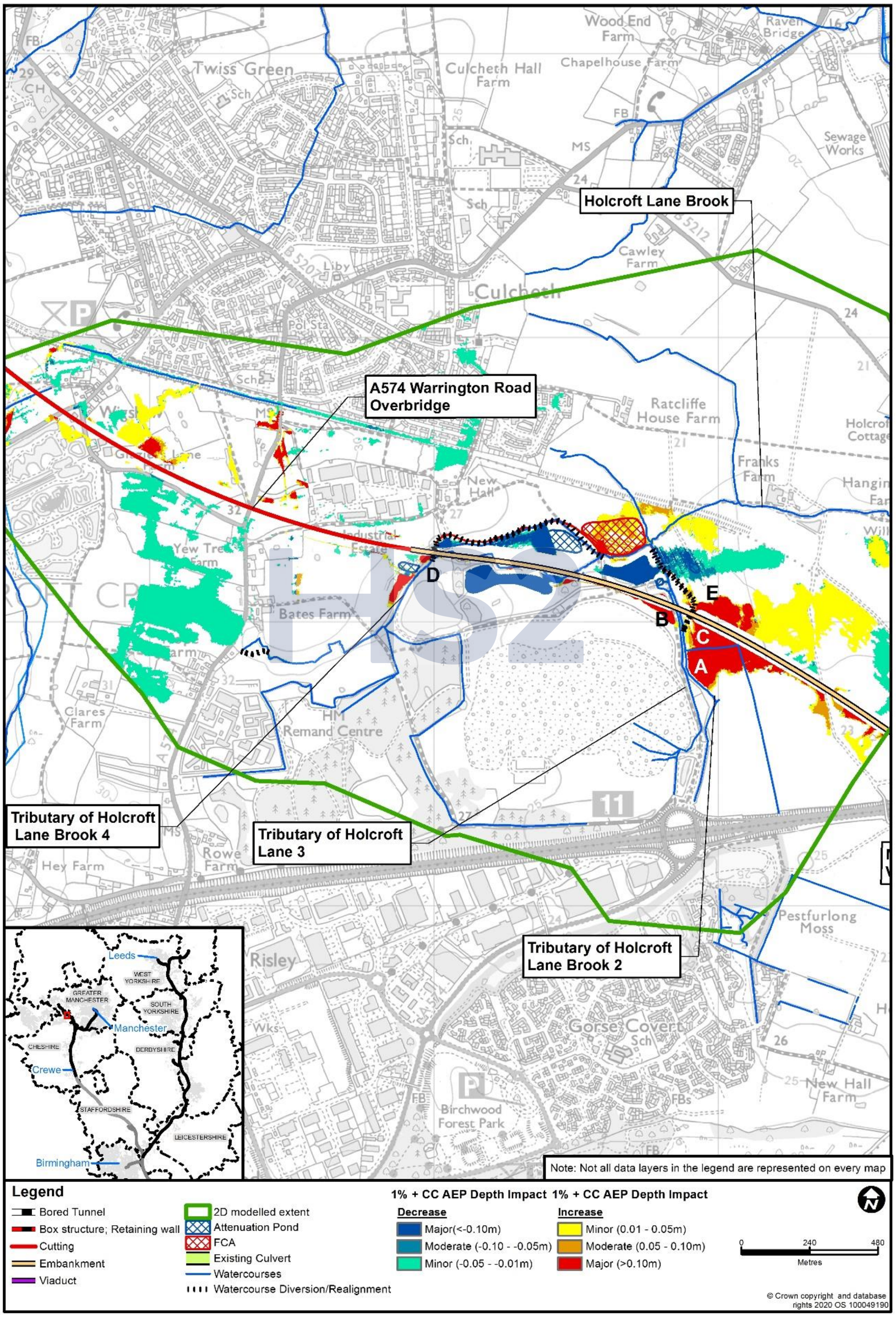


Figure A 2: Tributaries of Holcroft Lane Brook 2, 3 and 4 impact map for 1.0% AEP + CC event (1 in 100 year plus climate change)



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High Speed Two (HS2) Limited
Two Snowhill
Snow Hill Queensway
Birmingham B4 6GA
Freephone: 08081 434 434
Minicom: 08081 456 472
Email: HS2enquiries@hs2.org.uk