E172

High Speed Rail (West Midlands - Crewe)

Environmental Statement

Volume 5: Technical appendices

CA5: South Cheshire

Flood risk assessment (WR-003-005)

July 2017

ES 3.5.2.5.15

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Department for Transport

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1 Introduction

1.1 Structure of the water resources and flood risk appendices

1.1.1 The water resources and flood risk Appendices comprise both route-wide and community area specific documents. The route-wide Water resources and flood risk Appendices comprise:

- a Water Framework Directive compliance assessment (Volume 5: Appendix WR-001-000); and
- a water resources operation and maintenance plan (Volume 5: Appendix WR-005-000).

1.1.2 For the South Cheshire area (CA5) the area specific appendices comprise:

- a water resources assessment (Volume 5: WR-002-005); and
- a flood risk assessment (this appendix).

1.1.3 Hydraulic modelling reports, which describe the approach to assessing key flood risk issues identified within the study area, are included in Background Information and Data (BID)[1]. For the South Cheshire area (CA5) this document is the Hydraulic modelling report – Checkley Brook (Volume 5: Background Information and Data 004, BID-WR-004-010).

1.1.4 Maps (WR-01, WR-02, WR-05 and WR-06) referred to throughout this flood risk assessment are contained in the Volume 5, Water resources and flood risk assessment map book.

1.1.5 Issues associated with the Sequential Test and Exception Test in the National Planning Policy Framework (NPPF) are discussed on a route-wide basis in Volume 3.

1.2 Scope, assumptions and limitations

1.2.1 The purpose of this flood risk assessment is to consider the flood risk implications of the permanent works associated with the Proposed Scheme within the South Cheshire area.

1.2.2 Temporary works have not been assessed unless they are of a significant scale compared to the permanent works and have potential to adversely affect flood risk. The proposed temporary borrow pit is of a significant scale compared to the permanent works. However, it is assumed that this feature would not increase flood risk. Excavation of the borrow pit would be undertaken in accordance with the measures outlined in the draft CoCP, with the specific aim of not increasing flood risk to vulnerable receptors. The design of the temporary works would ensure that, if a flood does occur, the borrow pit would fill with floodwater. It is also assumed that the restored borrow pit area would cause no increase in flood risk. The area will be

[1] HS2 Ltd (2017), *High Speed Two (HS2) Phase 2a (West Midlands-Crewe), Background Information and Data, Hydraulic modelling reports, BID-WR-004*, www.gov.uk/hs2

restored to the existing ground levels, which will in turn restore the original floodplain hydraulic functionality. The permanent drainage of the restored borrow pit area will also aim to maintain existing surface water runoff characteristics.

1.2.3 All sources of flood risk are considered, other than tidal flooding.

1.2.4 Receptors considered in this assessment include the Proposed Scheme itself, other existing infrastructure assets, residential buildings, commercial buildings, and agricultural land and property potentially affected by the Proposed Scheme.

1.2.5 The assessment has involved an initial scoping study using existing available information, including information provided by statutory consultees and stakeholders.

1.2.6 Visual surveys have been undertaken of accessible water features to verify the dimensions of key hydraulic structures. Not all structures have been visually surveyed due to access constraints.

1.2.7 Hydraulic modelling has been undertaken in locations where the potential for impacts on flood risk were identified in the scoping study. This modelling has made best use of existing models provided by the Environment Agency. No new channel survey has been obtained. Floodplain geometry was however updated using Light Detection and Ranging (LiDAR) data. A number of assumptions have been made within the hydraulic models and these are described in detail in the hydraulic modelling reports in the BID-WR-004[1].

1.2.8 The hydraulic modelling work is based on conservative assumptions about the potential hydraulic impacts of the structures proposed. All models will require refinement during the detailed design using additional topographical survey data. The models will then require further development to reflect the detailed design of hydraulic structures and flood risk mitigation measures.

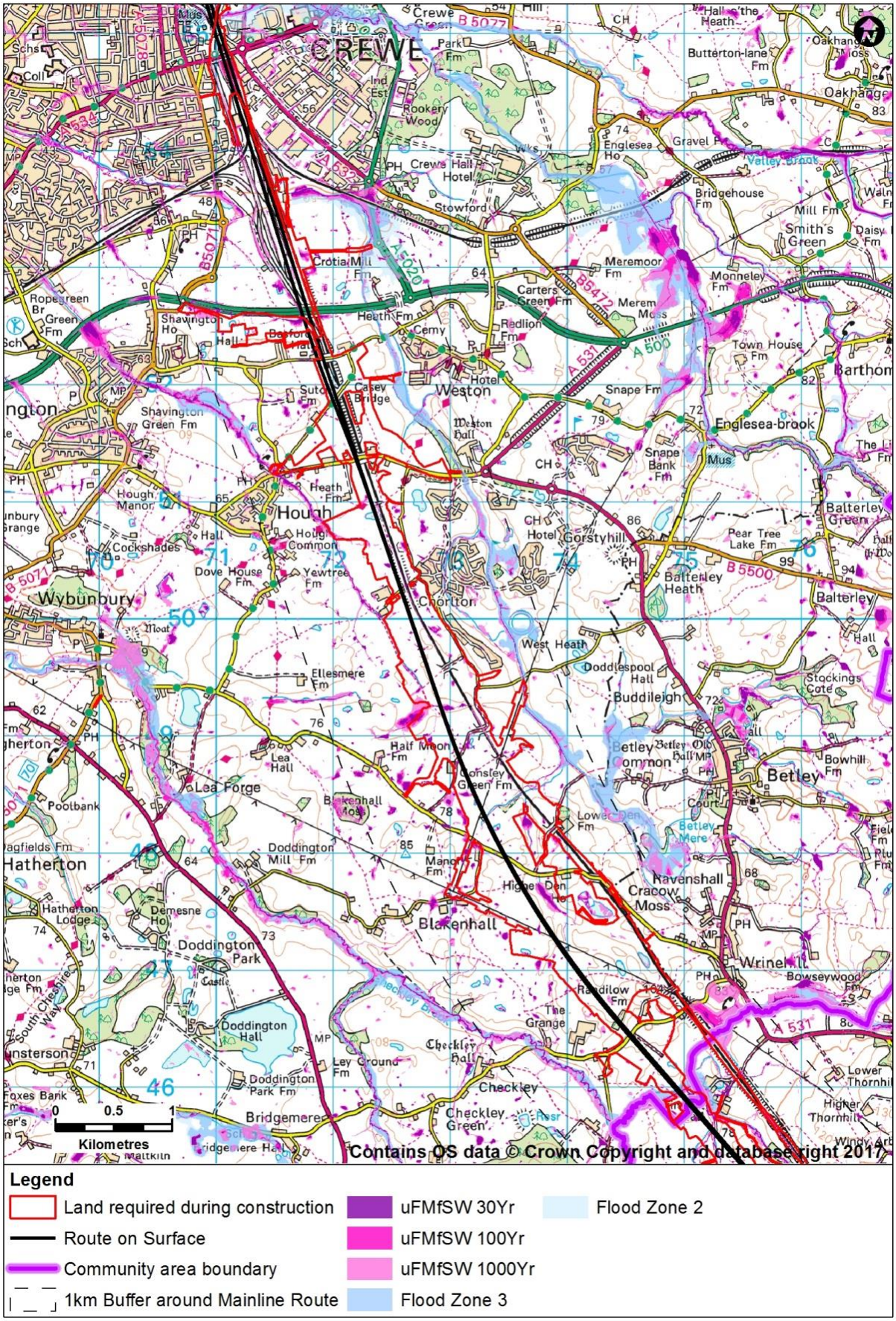
1.3 Location and extent

1.3.1 The location and extent of the study area is shown in Figure 1. The study area extends 1km from the centreline of the route of the Proposed Scheme. All flood risk receptors have been identified within these limits. If modelling assessments identified potential impacts beyond these limits, the study area has been extended accordingly.

1.3.2 Figure 1 also shows the extent of the land required during construction of the Proposed Scheme, Environment Agency Flood Zones 2 and 3[2], as well as the areas at risk from surface water flooding. The flood zone information in based on the Environment Agency's flood map for planning (river and sea) and the updated flood map for surface water (UFMfSW).

[2] Flood Zone 2 comprises land assessed as having between a 1 in 100 (1%) and 1 in 1,000 (0.1%) annual probability of river flooding; Flood Zone 3 comprises land assessed as having between a 1 in 100 (1%) or greater annual probability of river flooding

Figure 1: Location and extent of the study area



2 Policy context and consultation

2.1 National

2.1.1 The Proposed Scheme design has been developed in general accordance with the requirements of the National Planning Policy Framework (NPPF)[3]. This aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere. The Sequential Test and Exception Test in NPPF aim to achieve these policy objectives.

2.1.2 The Flood and Water Management Act 2010 requires the Environment Agency to 'develop, maintain, apply and monitor a strategy for flood and coastal erosion risk management in England'. The Environment Agency therefore has oversight of all matters related to flood risk and is a statutory consultee for flood risks associated with main rivers and reservoirs.

2.1.3 The Environment Agency has been consulted throughout the process of undertaking this assessment and has provided extensive data and guidance on the interpretation of policy.

2.2 Regional and Local

2.2.1 Under the Flood and Water Management Act 2010, the statutory consultee for all matters related to local flood risk, including works affecting ordinary watercourses, is the Lead Local Flood Authority (LLFA). Cheshire East Council (CEC) is the LLFA in the South Cheshire area. A series of meetings has been held with CEC LLFA technical specialists to gather information, develop the approach adopted in this assessment and agree principles related to the hydraulic design of the Proposed Scheme.

2.2.2 The CEC Preliminary Flood Risk Assessment (PFRA)[4] was published in 2010 however the CEC Local Flood Risk Management Strategy (LFRMS) is currently in draft and not available for review.

2.2.3 The Local Planning Authorities (LPA) Crewe and Nantwich Borough Council (now part of Cheshire East Council) have produced SFRAs that cover their administrative boundaries[5,6]. The key flood risk objectives outlined in the SFRA are to: seek flood risk reduction through spatial planning and site design, reduce surface water runoff from new developments and agricultural land, enhance and restore the river corridor, protect and promote areas for future flood alleviation schemes and improve flood awareness and emergency planning. The Proposed Scheme design has sought to align with these objectives where reasonably practicable.

[3] Department for Communities and Local Government (2012), *National Planning Policy Framework*
[4] Jacobs (2010), *Cheshire East Preliminary Flood risk Assessment*
[5] JBA (2008), *Crewe and Nantwich Strategic Flood Risk Assessment*
[6] JBA (2013), *Cheshire East Council Strategic Flood Risk Assessment*

3 Approach to flood resilience

3.1 Overall aims

3.1.1 The Proposed Scheme aims to avoid an increase in the risk of flooding from all sources, taking into account the projected impact of climate change.

3.2 Route selection

3.2.1 The route of the Proposed Scheme has been selected based on application of the sequential approach advocated in NPPF[3]. This approach aims to steer new development to areas with the lowest probability of flooding. Avoidance of areas with a high probability of flooding was a key consideration in the original Appraisal of Sustainability[7] and consequently the route of the Proposed Scheme avoids flood zones wherever reasonably practicable. It is recognised within NPPF that essential transport infrastructure has to cross areas at risk of flooding, for example at river crossings. In such circumstances, the Exception Test requires that it be demonstrated that the infrastructure would be safe from flooding over its lifetime, would not increase flood risk elsewhere and that the wider benefits to society outweigh flood risk. The manner in which the scheme aligns with the Sequential Test and Exception Test in NPPF is outlined in Volume 3, Water resources and flood risk.

3.3 Design standard

3.3.1 The Proposed Scheme will be protected against flooding from any source during the current 1 in 1,000 (0.1%) annual probability flood, with water levels not rising closer than 1m to the top of rail level.

3.4 Hydraulic capacity

3.4.1 In locations where the route of the Proposed Scheme will cross watercourses or surface water flow paths, the design aim is for structures to accommodate flood flows up to and including the 1 in 100 year (1%) annual probability storm with an allowance for climate change without increasing flood risk.

3.4.2 A minimum of 600mm freeboard above the 1 in 100 (1%) annual probability plus climate change design flood has been allowed to the soffit of all bridges and viaducts.

3.4.3 A minimum of 300mm freeboard above the 1 in 100 (1%) annual probability plus climate change design flood has been allowed to the soffit of all culverts.

3.5 Floodplain storage

3.5.1 Watercourse crossings have been designed to reduce losses of floodplain storage. Wherever such losses are anticipated, provision has been made to replace this storage at the affected location on a 'level for level' and 'volume for volume' basis.

[7] HS2, *Appraisal of Sustainability*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/68981/options-for-phase-two-of-the-high-speed-rail-network-appraisal-of-sustainability.pdf

3.6 Maintenance access

3.6.1 Four metres vertical clearance above floodplain ground level has been provided to the underside of viaducts wherever practicable to ensure access to riverbanks for inspection and maintenance purposes. Piers have been set eight metres back from the bank top, wherever reasonably practicable.

3.7 Off-site effects

3.7.1 The design of the Proposed Scheme's drainage systems aims to ensure that there will be no significant increases in flood risk to vulnerable receptors downstream, during storms up to and including the 1 in 100 (1%) annual probability design flood, with an allowance for climate change.

3.8 Climate change allowances

3.8.1 In general the design of the Proposed Scheme has adopted a precautionary approach to potential future increase in peak river flows and rainfall intensities, using the recommended post 2080s allowances within the latest guidance provided by the Environment Agency[8]. The details of how this guidance should be applied in practice to the Proposed Scheme, as outlined below, have been agreed with Environment Agency.

Increases in peak river flow

3.8.2 The risk based approach within the guidance recommends selection of a suitable allowance, from a range of possibilities, for use in the assessment and design of flood risk management for new buildings or infrastructure, based on the consequences should that value be exceeded.

3.8.3 Table 1 shows the range of potential allowance categories for use in the North West river basin district in which the South Cheshire area lies.

Table 1: Allowance percentages (post 2080) for each allowance category in the North West river basin

River basin	Allowance category	Allowance
North West	H++	95%
	Upper end	70%
	Higher central	35%
	Central	30%

3.8.4 The allowance category used depends on both the vulnerability to flooding of the receptor potentially affected and the flood zone within which it is located. Table 2

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

shows the basis on which the allowance categories have been selected for use in the preliminary hydraulic design of viaducts, bridges and culverts. The vulnerability of each receptor has then been classified using Table 2 of the planning practice guidance on flood risk and coastal change[9], which is aligned with the receptor value in the Scope and Methodology Report (SMR)[10] and its Addendum[11].

Table 2: Allowance categories for each existing property or land use in different flood zones

Flood Zone	Receptor Vulnerability	Allowance Category
Flood Zone 2	Essential infrastructure	Upper end
	Highly vulnerable	
	More vulnerable	Higher central
	Less vulnerable	Central
	Water compatible	Central
Flood Zone 3a	Essential infrastructure	Upper end
	Highly vulnerable	
	More vulnerable	
	Less vulnerable	Higher central
	Water compatible	Central
Flood Zone 3b	Essential infrastructure	Upper end
	Highly vulnerable	
	More vulnerable	
	Less vulnerable	
	Water compatible	Central

3.8.5 Railways, motorways and 'A' roads with one or two number identifiers (e.g. A1 or A34) are considered essential infrastructure, while all other roads are considered less vulnerable.

[9] Environment Agency, *Flood risk assessments: climate change allowances,* http://www.gov.uk/guidance/flood-riskoassessments-climate-change-allowances
[10] Environmental Impact Assessment Scope and Methodology Reports, Volume 5: Appendix CT-001-001
[11] Environmental Impact Assessment Scope and Methodology Reports, Volume 5: Appendix CT-001-002

3.8.6 The vulnerability level used for each assessment corresponds with the existing property or land use with the highest vulnerability within the area considered. For example, if the consequence of a culvert being under-capacity would be to cause flooding of a major road, or of flood-vulnerable components of the Proposed Scheme itself, the culvert is designed to accommodate an 'upper end' allowance for climate change. The probability of this allowance being exceeded post 2080 is considered to be 1 in 10 (10%).

Increases in peak rainfall intensity

3.8.7 A peak rainfall intensity allowance of 40% has been used as the basis for the preliminary design of track drainage, runoff attenuation elements and surface water catchments less than 5km^2.

H++ scenarios

3.8.8 This extreme scenario represents a credible upper limit to the changes that could potentially occur beyond the end of this century. Sensitivity analyses undertaken to provide a high level assessment of the performance of the Proposed Scheme under 'design exceedance' conditions have used allowances that equal or exceed the H++ value provided in the guidance for the peak river flows, which for the North West river basin district is 95%, as indicated in Table 1.

4 Assessment methodology

4.1 Overview

4.1.1 The approach to flood risk assessment is based on the government's planning practice guidance on flood risk and coastal change, CIRIA Publication C624 'Development and flood risk: guidance to the construction industry' and the Design Manual for Roads and Bridges (DMRB)[12]. The assessment process has proceeded as follows:

- all existing potential sources of flooding have first been identified, together with the pathways or mechanisms by which they have potential to cause risk to life, economic or environmental damage, disruption or nuisance;
- all existing property and assets (receptors) at risk from these sources, and their relative vulnerability to flooding impacts, have then been determined;
- an assessment of the magnitude of the impacts at each of these receptors, taking into consideration the mitigation measures incorporated into the design, has then been completed; and
- the significance of the flood risk issues at affected receptors has been identified, together with suggestions for additional mitigation, where this is necessary to address any potentially significant effects identified.

4.2 Identification of relevant flood sources and pathways

4.2.1 The Environment Agency's flood map for planning (rivers and sea)[13] has been used to scope the baseline flood hazard associated with rivers and ordinary watercourses.

4.2.2 The updated flood map for surface water (uFMfSW)[14] has been used to scope surface water flood hazards. Infrastructure failure flood hazards have been scoped using the Environment Agency 'Risks of flooding from reservoirs'[13] national dataset. The British Geological Survey national dataset, areas susceptible to groundwater flooding (AStGWF)[15], has been used to scope the future risk of groundwater flooding.

4.2.3 At locations where there is potential for the Proposed Scheme to increase flood risk, hydraulic models have been used to assess the potential impacts in more detail.

4.3 Identification of receptors

4.3.1 Existing receptors with potential to be affected by the Proposed Scheme have been identified using Ordnance Survey (OS) mapping information and address point data. Receptor vulnerability is based on the definitions in Table 52 of the SMR, which is

[12] Highways Agency, *Design for Roads and Bridges*, http://www.standardsforhighways.co.uk/ha/standards/dmrb/
[13] Gov.uk, *Flood map for planning*, https://flood-map-for-planning.service.gov.uk//
[14] Gov.uk, *Long term flood risk information*, https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?easting=402498&northing=282043&address=100070518535
[15] British Geological Survey, *Susceptibility to groundwater flooding*, http://www.bgs.ac.uk/products/hydrogeology/groundwaterFlooding.html

aligned with Table 2 of the planning practice guidance on flood risk and coastal change[16].

4.4 Assessing impacts and effects

4.4.1 Impact magnitude has been considered in terms of increases in peak flood levels associated with floods with a range of annual probabilities. The significance of the resulting effects on flood risk reflect the vulnerability of the receptor and the magnitude of the predicted impact, as defined by the matrix in Table 3 below, which is based on Table 50 and Table 52 of the SMR.

Table 3: Significance of flood effects

Flood vulnerability of receptor	**Magnitude of impact on peak flood levels**			
	Negligible (< +/- 10mm)	Minor > 10mm ≤ 50mm	Moderate > 50mm ≤ 100mm	Major > 100mm
Very high	Negligible - not significant	Moderate adverse - significant	Major adverse - significant	Major adverse - significant
High	Negligible - not significant	Moderate adverse - significant	Moderate adverse - significant	Major adverse - significant
Moderate	Negligible - not significant	Minor adverse - not significant	Moderate adverse - significant	Moderate adverse - significant
Low	Negligible - not significant	Negligible - not significant	Minor adverse - not significant	Minor adverse - not significant

4.4.2 Regardless of the significance of the flood risk effects, the design aim will be to mitigate all impacts on flood risk during the detailed design phase.

[16] Department for Communities and Local Government (2016), Planning practice guidance and planning system, https://www.gov.uk/guidance/flood-risk-and-coastal-change

5 Flood risk baseline

5.1 Historical flooding incidents

5.1.1 There are very few historical records of flooding available for the South Cheshire area. The PFRA and Catchment Flood Management Plan (CFMP) give limited details of historic flooding on River Weaver, Valley Brook, and Gresty Brook. However, River Weaver is not crossed by the Proposed Scheme, whilst no interaction with Valley Brook and Gresty Brook will occur as the scheme will pass under these watercourses in tunnel.

5.2 Risks associated with rivers and ordinary watercourses

5.2.1 The key flood risk from main rivers and ordinary watercourses is that associated with the following:

- Checkley Brook / River Lea at the southern end of the South Cheshire area, and
- Valley Brook, and Gresty Brook to the south of Crewe town centre.

5.2.2 The areas at risk of flooding from these watercourses, the receptors potentially affected and the climate change allowances used in the design and the assessment of impact and effects are considered below.

Checkley Brook / River Lea

5.2.3 There were no existing models for Checkley Brook / River Lea in this area, and the Environment Agency Flood Maps are believed to be derived by National Generalised Modelling (JFLOW). As such, a new fluvial hydraulic model of these watercourses has been produced. The model has then been used to determine the flood extent resulting from the 1 in 100 (1%) annual probability flood with an allowance for climate change and to identify existing receptors that are at potential risk from river flooding.

5.2.4 Figure 2 shows the baseline 1 in 100 (1%) annual probability plus climate change flood extent, together with the receptors identified as being at potential risk from fluvial flooding.

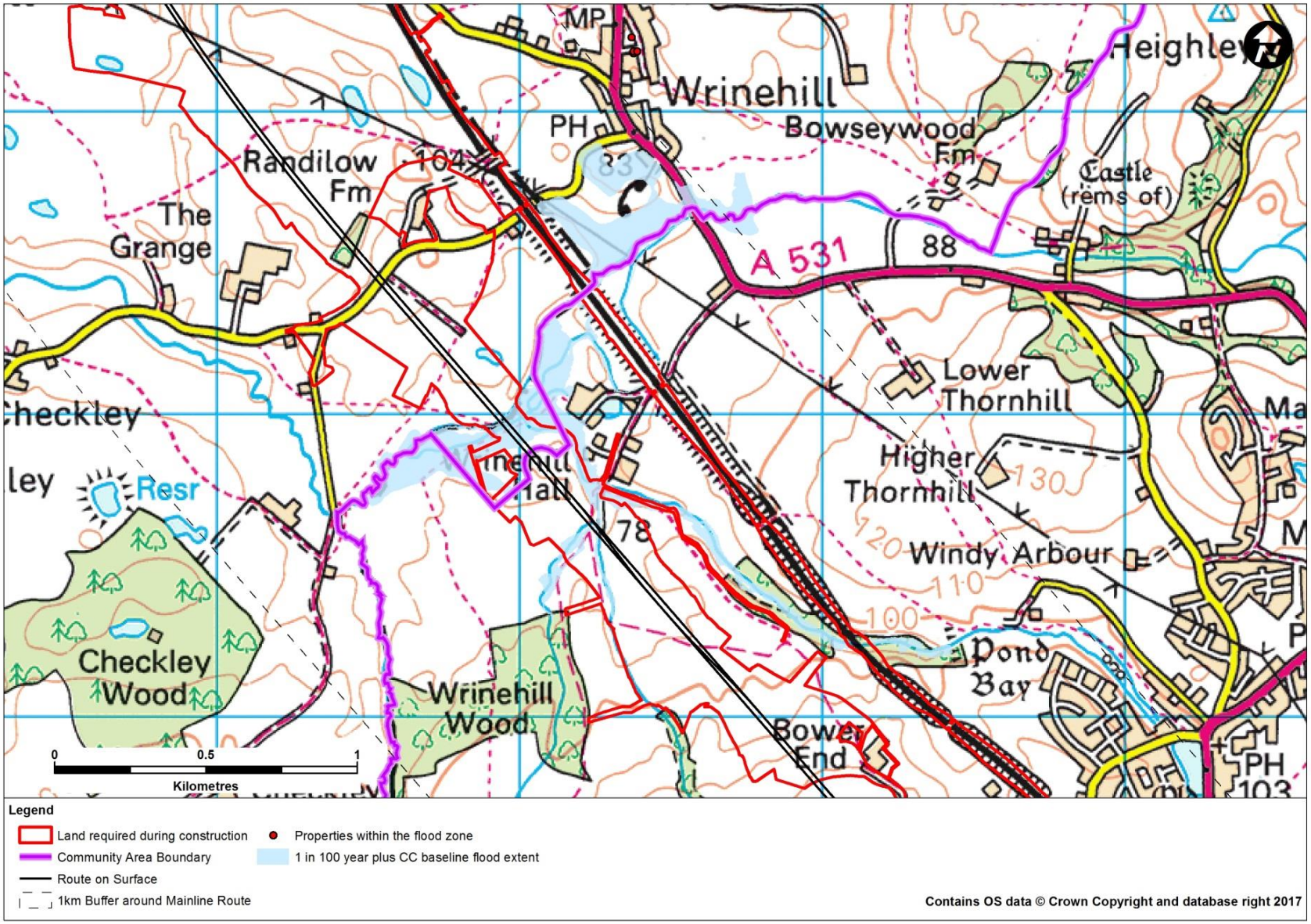
5.2.5 The receptors and their vulnerability located upstream (to the east) of the Proposed Scheme are listed below. The relative vulnerability to flooding of each receptor (as defined in NPPF and Tables 52 of the SMR) is also indicated:

- agricultural land north of the WCML (West Coast Main Line) (Makin Farm) (less vulnerable);
- A531 Main Road (less vulnerable); and
- Checkley Lane (less vulnerable).

5.2.6 The only receptor located downstream (to the west) of the Proposed Scheme is agricultural land, which is classed as less vulnerable to flooding.

5.2.7 A climate change allowance comprising a 30% increase in peak river flows has been adopted at this crossing.

Figure 2: Flood risk associated with River Lea and Checkley Brook



5.3 Risks associated with surface water

5.3.1 This section presents the risk associated with surface water as shown by the Environment Agency's uFMfSW data set for the 1% (1 in 100) annual probability flood.

5.3.2 As presented in Figure 3 and Figure 4, the following additional receptors (with relative vulnerabilities as indicated) are at risk of flooding from surface water:

- agricultural land at Randilow Farm (less vulnerable);
- agricultural land at Higher Den House (less vulnerable);
- residential properties at Mill Lane (more vulnerable);
- the WCML south of Waybutt Lane (essential infrastructure);
- agricultural land north of Half Moon Farm (less vulnerable);
- residential properties at Hough (more vulnerable);
- commercial properties within Crewe Gates Farm Industrial Estate (less vulnerable);
- residential properties at Bray Close, Crewe (more vulnerable); and
- residential properties south of Maw Green Road, Crewe (more vulnerable).

5.3.3 A climate change allowance of 40% increase in peak flows has been adopted at these surface water flow path crossings, because the attachment areas are all less than 5km^2.

Figure 3: Surface water flood risk (southern part of the study area)

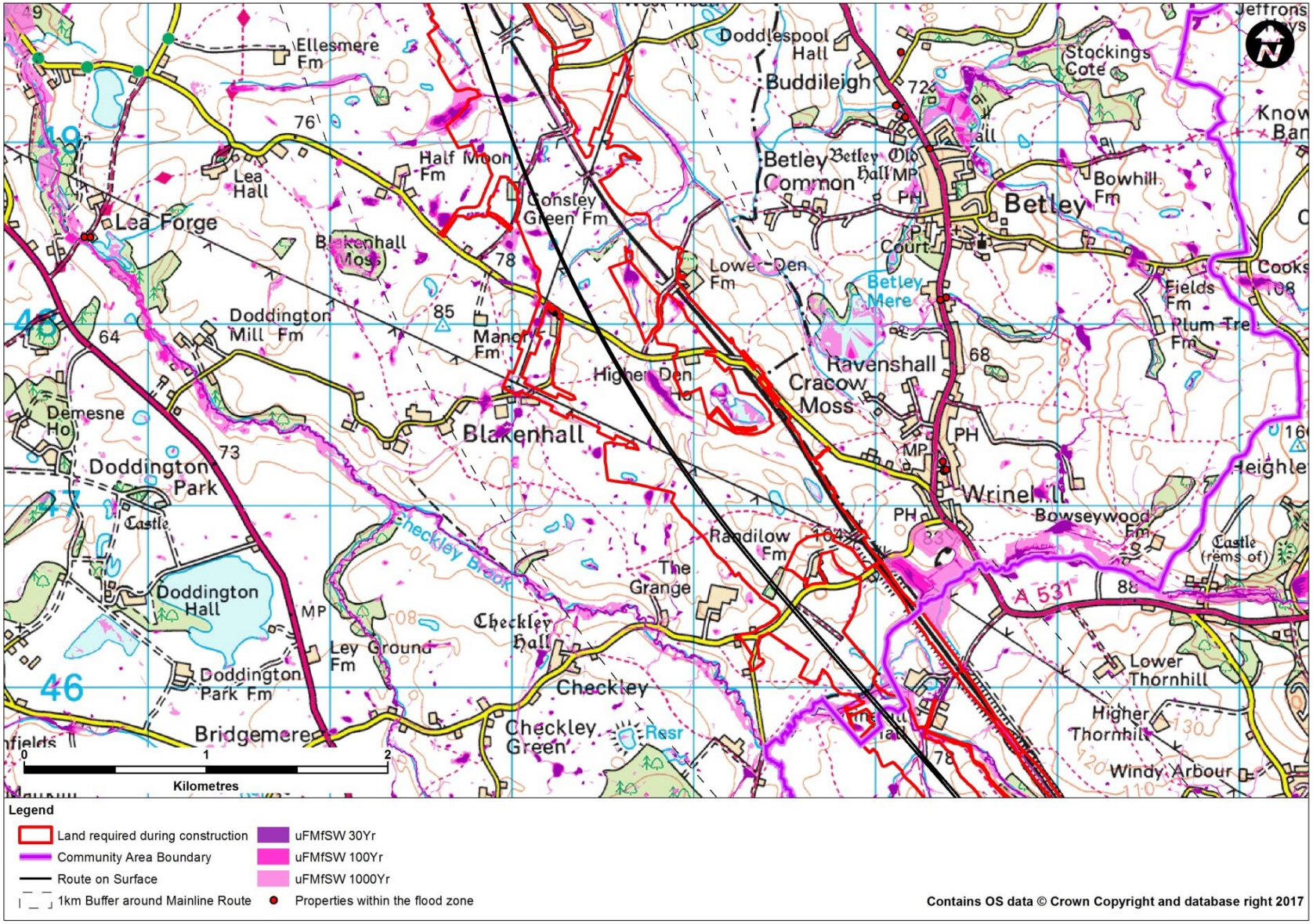
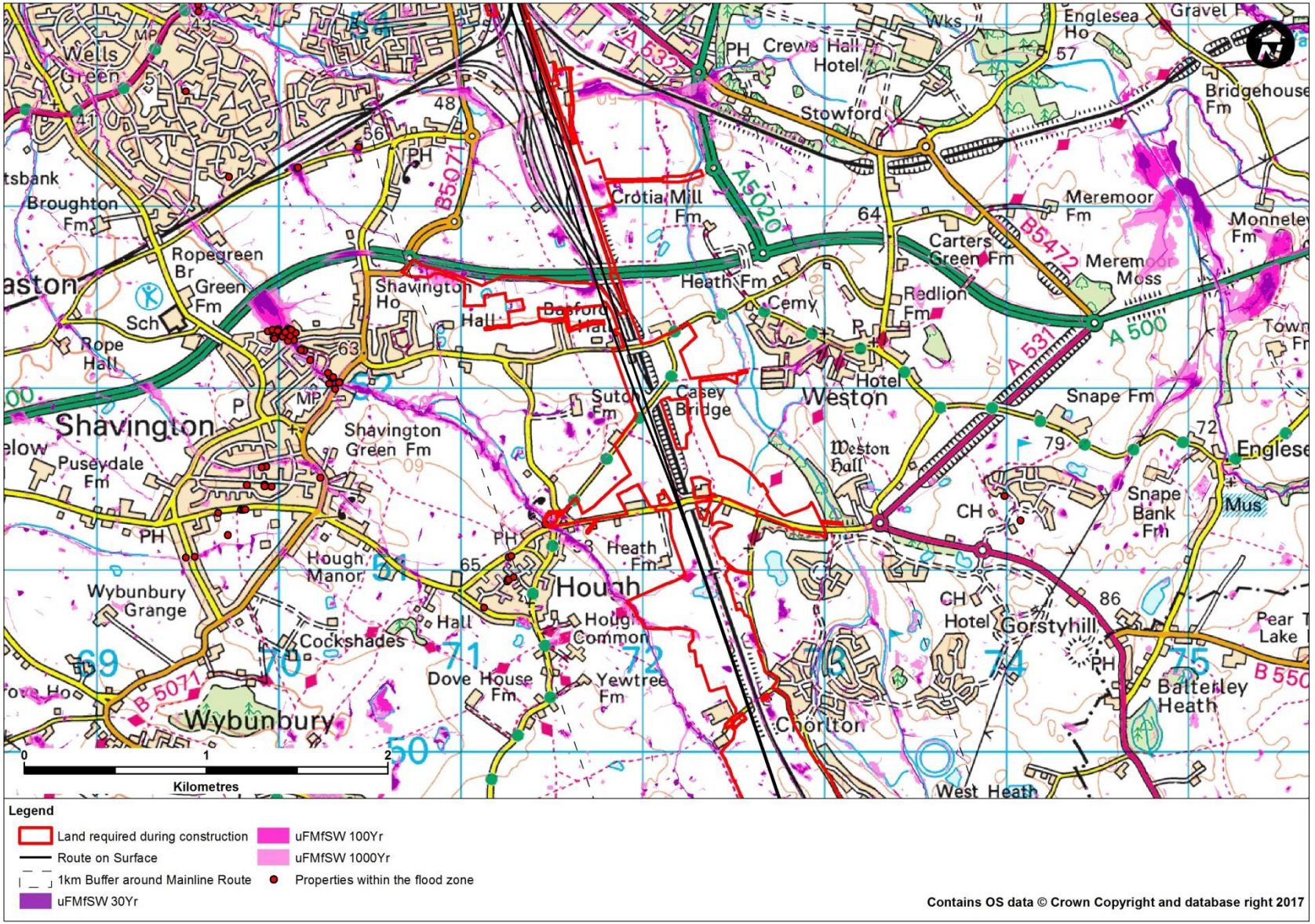


Figure 4: Surface water flood risk (northern part of the study area)



5.4 Risks associated with groundwater

5.4.1 The AStGWF provides the main dataset used to assess the future risk of groundwater flooding. The assessment of susceptibility is based on rock type and estimated groundwater levels during periods of extended intense rainfall. The AStGWF map uses four susceptibility categories to show the proportion of each 1km grid square where geological and hydrogeological conditions combine to indicate a potential risk that groundwater flooding might occur. It does not show the likelihood of groundwater flooding actually occurring.

5.4.2 AStGWF in the South Cheshire area generally follow the main river networks, and where more permeable Alluvium and Glaciofluvial Deposits overlie low permeability Tills.

5.4.3 Based on historic evidence, the CEC SFRA states that groundwater flooding in the South Cheshire area is not considered to be significant.

5.5 Risks associated with artificial sources

5.5.1 Flooding from artificial water bodies may occur due to failure of an impounding structure, such as a dam or canal embankment. A number of structures, including fisheries have been identified within the South Cheshire area. However these appear to be below ground level, and as such there is no impounding structure at risk of failure.

5.5.2 The following man-made features have been identified within the study area as being a potential source of flood risk:

- The Environment Agency's 'Flood risk from reservoirs' mapping identifies a single area at risk from a failure of a reservoir with a volume in excess of 25,000 m^3. This is located downstream of the Betley Hall Lake to the east of the Proposed Scheme. The flood extent is shown to extend approximately 1km to the east of the Proposed Scheme at its closets point and would not affect or be affected by the Proposed Scheme; and
- major water supply pipelines and sewerage (foul and surface water) infrastructure have been identified and are accounted for on the Proposed Scheme drawings.

5.5.3 There are no canals located within the South Cheshire area.

5.6 Summary of baseline flood risk

5.6.1 Table 4 provides a summary of all the relevant sources of flood risk identified, the receptors potentially affected, their relative vulnerability and the climate change allowance used in the modelling assessments and calculations.

Table 4: Summary of baseline flood risk

Source / Pathway	Receptors	Data Source	Highest Receptor Vulnerability Level	Climate Change Allowance used for assessment
River Lea / Checkley Brook	Agricultural land north of the WCML (Makin Farm)	1 in 100 (1%) annual probability flood extent with allowance for climate change	Less vulnerable	30%
	A531 Main Road			
	Checkley Lane			
Surface water flow paths	Agricultural land at Randilow Farm	uFMfSW 1% AEP	Essential Infrastructure	40%
	Agricultural land at Higher Den House			
	Residential properties at Mill Lane			
	Agricultural land north of Half Moon Farm			
	Residential properties at Hough			
	Crewe Gates Farm Industrial Estate			
	Residential properties at Bray Close, Crewe			
	Residential properties south of Maw Green Road, Crewe			
	the WCML south of Waybutt Lane			

6 Flood risk impacts and effects

6.1 Rivers and ordinary watercourses

Viaducts

6.1.1 The Proposed Scheme within the South Cheshire area includes crossings of two watercourses on a single viaduct: River Lea and Checkley Brook.

6.1.2 The hydraulic model of River Lea and Checkley Brook has been used in the design and assessment of the Proposed Scheme in the following ways:

- to define the 1% annual probability flood extent including an allowance for climate change;
- to confirm supporting abutments and embankments of the viaducts are located outside the 1% annual probability flood extent including an allowance for climate change, where reasonably practical; and
- to determine the impact of flood levels of intermediate piers or any other permanent features associated with the Proposed Scheme.

6.1.3 Details of all the hydraulic modelling assessment undertaken of these watercourses can be found in the supporting hydraulic modelling report contained in the BID[1]. The results of this assessment are reported below.

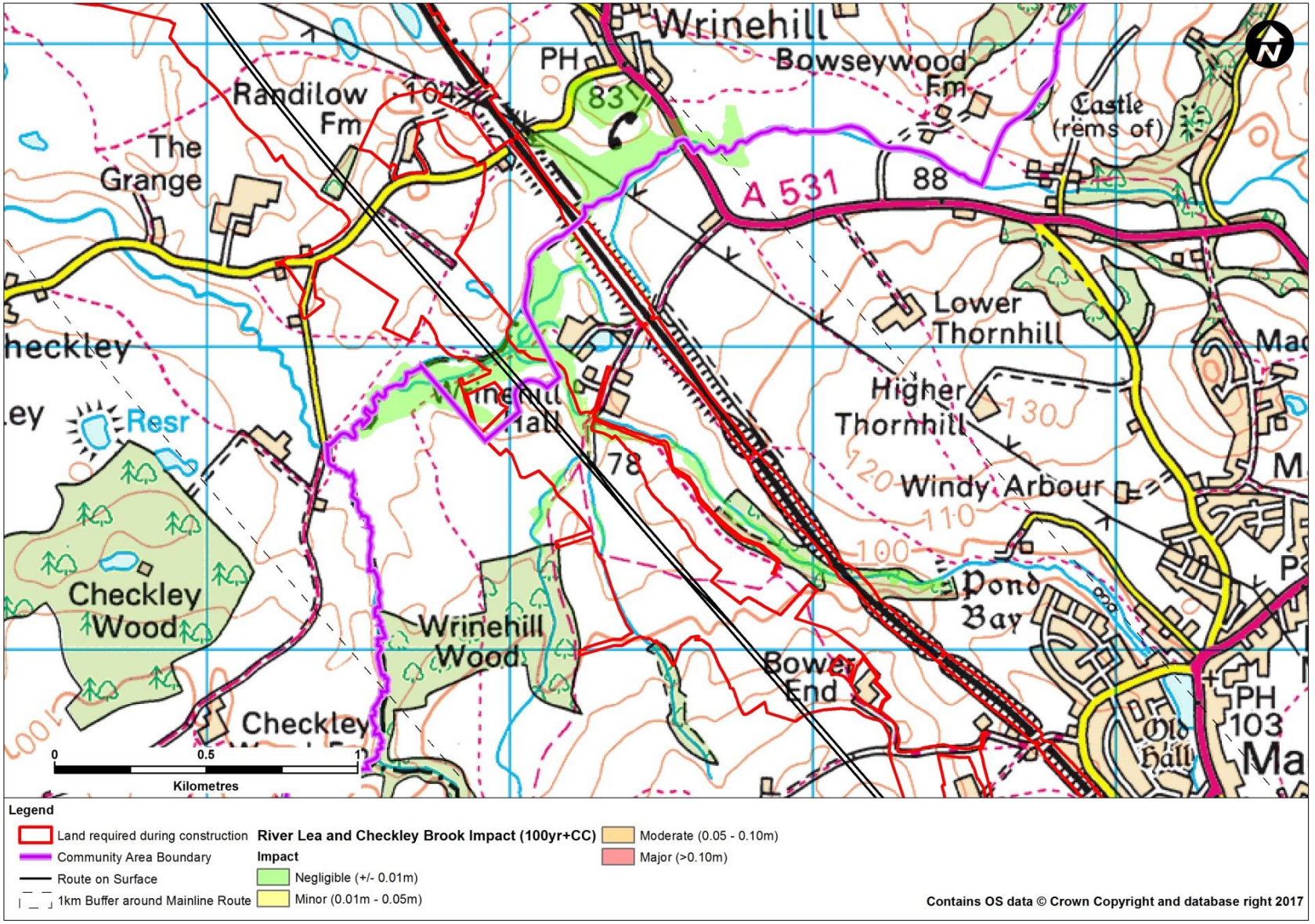
River Lea and Checkley Brook

6.1.4 The effect of the piers on flood water levels at River Lea and Checkley Brook is shown in Figure 5.

6.1.5 The results of the hydraulic model study indicate that the capacity of the channels at Checkley Brook viaduct will be sufficient to convey the estimated 1 in 100 (1%) annual probability plus climate change flood flow with a negligible impact on flood levels upstream and downstream. It also indicates that the piers will cause a minor, localised impact on peak flood levels, affecting undeveloped farmland. As such it would be a minor impact affecting a moderate value receptor and so is a minor adverse effect, which is not significant.

6.1.6 Sensitivity analysis was undertaken to establish whether the viaduct could affect peak flood levels at the WCML, should higher flows occur. This analysis again indicated that the impact of the viaduct on upstream flood levels would not extend as far as the WCML.

Figure 5: Post development flood risk on River Lea and Checkley Brook



Culverts and channel diversions

6.1.7 The uFMfSW data set has been used to indicate the potential flood extent generated and the receptors affected along smaller watercourses (see Section 5.3), where culvert crossings are proposed.

6.1.8 The following calculation procedure has been undertaken to size the culverts:

1. use of the Revitalised Rainfall-Runoff Model version 2.2. (ReFH2) to determine the peak flow generated during the 1 in 100 (1%) annual probability storm event;
2. determination of the appropriate climate change allowance to be applied following the procedure outlined in Section 3.8;
3. determination of the existing gradient of the watercourse using OS Mapping and LiDAR data;
4. determination of the likely roughness characteristics of the proposed culverts;
5. selection of a structure with the capacity to convey the 1 in 100 (1%) annual probability peak flow, incorporating the appropriate allowance for climate change; and
6. ensuring a minimum of 300mm freeboard to the pipe soffit above this design flood level.

6.1.9 The details of the culvert design applied to the ordinary watercourses are provided in Table 5.

Table 5: Details of culvert design at ordinary watercourse crossings

Watercourse/Location	Structure name	Calculated 1%AEP flow (m^3/s)	Climate change allowance	Culvert dimensions (m)	Culvert capacity
Tributary of Mere Gutter	Blakenhall South culvert	0.07	40	1.35 x 1.35	1.41
Tributary of Mere Gutter	Blakenhall spur culvert	0.06	40	1.35 x 1.35	1.41
Tributary of Mere Gutter	Gonsley drop inlet culvert	0.32	40	1.35 x 1.35	1.41
Swill Brook	Half Moon inverted siphon	0.70	40	Two box culverts each 1.35 x 1.35	1.41

6.1.10 Table 5 illustrates that the minimum culvert dimension proposed, 1.35m x 1.35m, has ample capacity to convey the predicted peak flows. As such the magnitude of the flood risk impacts on local receptors is likely to be negligible.

6.1.11 Each of these ordinary watercourse crossings is associated with a minor localised channel realignment to reduce the length of culvert.as far as reasonably practicable.

6.1.12 The ordinary watercourses identified are also affected by highway diversions and permanent access requirements at the following locations:

- Wrinehill Road, affecting a tributary of Mere Gutter;
- South Crewe mid-point auto-transformer station access road, affecting Swill Brook; and
- unnamed WCML culvert extensions under access tracks 1-4, affecting a tributary of Mere Gutter.

6.1.13 The design of culverts required to convey water under highways and permanent access roads will follow the procedures outlined in Section 6.1.8. As such the magnitude of the flood risk impacts on local receptors is likely to be negligible.

6.2 Surface water

6.2.1 As outlined in Section 5.3, the uFMfSW data set and inspection of topographical survey information has identified surface water flow paths that are not represented by any formal channel features and so are not classed as formal watercourses.

6.2.2 These flow paths have been addressed in the design of the Proposed Scheme by providing culverts and/or channel features which will collect and convey surface water from one side of the route of the Proposed Scheme to the other.

6.2.3 The design process outlined in Section 6.1.7 has also been followed to size these culverts and their associated channels. In this way the existing flow paths are preserved and the flood response characteristics of the local area will remain unchanged.

6.2.4 Details of the culvert and channel design are provided in Table 6.

Table 6: Details of culvert design at surface water flow paths

Watercourse/Location	Structure/feature name	Calculated 1%AEP flow	Climate change allowance	Culvert/channel dimensions (m)	Calculated Channel capacity
Flow path at Randilow South (Checkley Brook)	Randilow South culvert	0.05	40	1.35 x 1.35	1.41
Flow path at Randilow South (Checkley Brook)	Randilow North culvert	0.12	40	1.35 x 1.35	1.41
Flow path at Blakenhall	Blakenhall drop inlet culvert	0.12	40	1.35 x 1.35	1.41
Flow path at Den Lane	Den Lane spur culvert	0.12	40	1.35 x 1.35	1.41

6.2.5 By following this design approach the local flood risk characteristics are preserved and the risk to the receptors outlined in Section 5.6 is unchanged. As such the magnitude of flood risk to these receptors is deemed to be negligible.

6.2.6 This sizing convention will be carried through the design stages unless a change in size is found to be beneficial to flood risk at the more detailed design stages.

6.2.7 The surface water flow paths identified are also affected by highway diversions and permanent access requirements at the following locations:

- access road culvert at Wrinehill package substation, affecting flow path to Checkley Brook;
- access road culvert at Grange Farm, affecting flow path to Checkley Brook;
- maintenance access point culvert, affecting flow path at Den Lane;
- access road culvert, affecting flow path to Swill Brook; and
- access road culvert, affecting flow path to Swill Brook.

6.2.8 The design of culverts required to convey water under highways and permanent access roads will follow the procedures outlined in Section 6.1.8. As such, the magnitude of the flood risk impacts on local receptors is likely to be negligible.

6.3 Groundwater

6.3.1 The principal mechanism by which the Proposed Scheme could increase groundwater flood risk is where sub surface structures of lower permeability than the existing geology, such as lined tunnels or pile walls, may act as a barrier to groundwater flow and have the potential to cause a rise in groundwater level in the vicinity of these structures. Other below ground features which could cause changes to the local groundwater levels, such as drained cuttings, are not assumed to increase groundwater flood risk as the drainage design will take account of groundwater flows entering the cutting.

6.3.2 To assess the possible changes to groundwater levels and flow, and the associated change in groundwater flood risk, a high level assessment of the groundwater conditions along the route has been undertaken to understand where the Proposed Scheme is likely to interact with groundwater.

6.3.3 In the South Cheshire area, the Crewe South Portal will be in a retained cutting, within the Glaciofluvial Deposits Secondary A aquifer. The Chorlton retaining wall 6 will also be constructed in the Glaciofluvial Deposits Secondary A aquifer. Local groundwater levels are not known with certainty though they are potentially shallow and the AStGWF shows that currently there is potential for groundwater flooding of property situated below ground level at these locations. If the portal and retaining wall intersects groundwater there is potential for local changes to groundwater level, and therefore potential to increase risk of groundwater flooding locally. Ground investigation during detailed design is required to confirm groundwater levels and ground conditions, and drainage systems will be designed to reduce any apparent risks.

6.3.4 In the area of the borrow pit north of Checkley Lane, groundwater levels in the Glaciofluvial Deposits Secondary A aquifer are not known though there is potential for groundwater levels to be shallow and groundwater flow is likely to follow the natural topographic gradient. The borrow pit will be backfilled to existing ground level as part of the planned restoration. It is assumed that the backfill material will be of lower

permeability than the existing Glaciofluvial Deposits and may therefore present a barrier to groundwater flow. The restoration plans will include land drainage measures. These will be designed in detail following ground investigation and monitoring, to ensure no overall increase in groundwater flood risk.

6.4 Artificial sources

6.4.1 As presented in Section 5.5, no risk of flooding from artificial sources has been identified in the South Cheshire area. As such, there is no risk to the scheme from such sources, and there is no risk that the construction of the scheme could result in the consequences of flooding from such sources being made worse.

6.4.2 Major water supply pipelines and sewerage (foul and surface water) infrastructure have been identified and are accounted for on the Proposed Scheme drawings as presented in CT-05. This infrastructure has been identified and diverted where appropriate. Measures will be taken to safeguard the local receptors during this diversion process.

6.4.3 The Proposed Scheme does not change the flood risk posed by failure of artificial sources.

6.5 Off-site impacts and effects (surface water management)

6.5.1 Runoff from the footprint of the Proposed Scheme could occur more rapidly post-construction due to steeper slope angles and the permeability of the newly-created surfaces.

6.5.2 The design of drainage systems aims to ensure that there will be no significant increases in flood risk downstream, during storms up to and including the 1 in 100 (1%) annual probability design event, with an allowance for climate change.

6.5.3 Balancing ponds for new sections of highway and railway drainage have been sized on a precautionary basis, pending more detailed information about the permeability and runoff characteristics of existing and proposed ground surfaces.

7 Additional flood risk management measures

7.1.1 The assessment has identified no requirement for additional flood risk mitigation beyond that embedded into the design of the Proposed Scheme.

7.1.2 The next stage of the design process will involve incorporation of topographical survey information into all of the existing hydraulic models to improve how they represent the existing watercourses. The areas of replacement flood storage identified will be incorporated into the models and the detailed design of all the viaducts, bridges and culverts will be developed with the aim of all impacts on peak flood level being mitigated as far as is reasonably practicable.

7.1.3 Where inverted siphons are to be constructed on surface water flow paths with no permanent flow, such as at Half Moon inverted siphon, clearance of the siphon will be incorporated into the HS2 asset maintenance programme to ensure its long term operation. Should this siphon fail to operate, as it is located upstream of a cutting, any flow out of channel would overflow into the cutting and be intercepted by the track drainage. As such, there would be no risk to any other receptors other than the Proposed Scheme.

7.1.4 The above activities will be undertaken in close consultation with the Environment Agency and the LLFA. If any residual effects are identified, the affected landowners would also be consulted. The aim will be to ensure that no parties are affected by unacceptable increases in flood risk.

8 Summary of significant flood risk effects

8.1.1 No significant flood risk effects have been identified within the South Cheshire study area.

9 Conclusions

9.1.1 The analysis undertaken indicates that it is likely that it will be possible to develop a detailed design for the Proposed Scheme that does not increase flood risk.

9.1.2 Further hydraulic modelling and design refinement of embedded mitigation measures will be undertaken at the detailed design stage.

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