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High Speed Rail (West Midlands - Crewe)

Environmental Statement

Volume 5: Technical appendices

CA4: Whitmore Heath to Madeley

Flood risk assessment (WR-003-004)

July 2017

ES 3.5.2.4.15

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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 Whitmore Heath to Madeley (CA4), the area specific appendices comprise:

- a water resources assessment (Volume 5: WR-002-004); 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]). These documents comprise of:

- Hydraulic modelling report – Meece Brook (Background Information and Data: BID-WR-004-008);
- Hydraulic modelling report – River Lea (Background Information and Data: BID-WR-004-009); and
- 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 Whitmore Heath to Madeley area.

1.2.2 Temporary works have not been assessed unless they are of a significant scale compared to the permanent works proposed and have potential to adversely affect flood risk. The proposed temporary borrow pit is of a significant scale compared to the

[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

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 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 Rangin (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[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 stage 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 centre line of the route of the Proposed Scheme. All flood risk receptors have been identified within these limits. If modelling assessments were to identify potential impacts beyond these limits, the study area would have been extended accordingly.

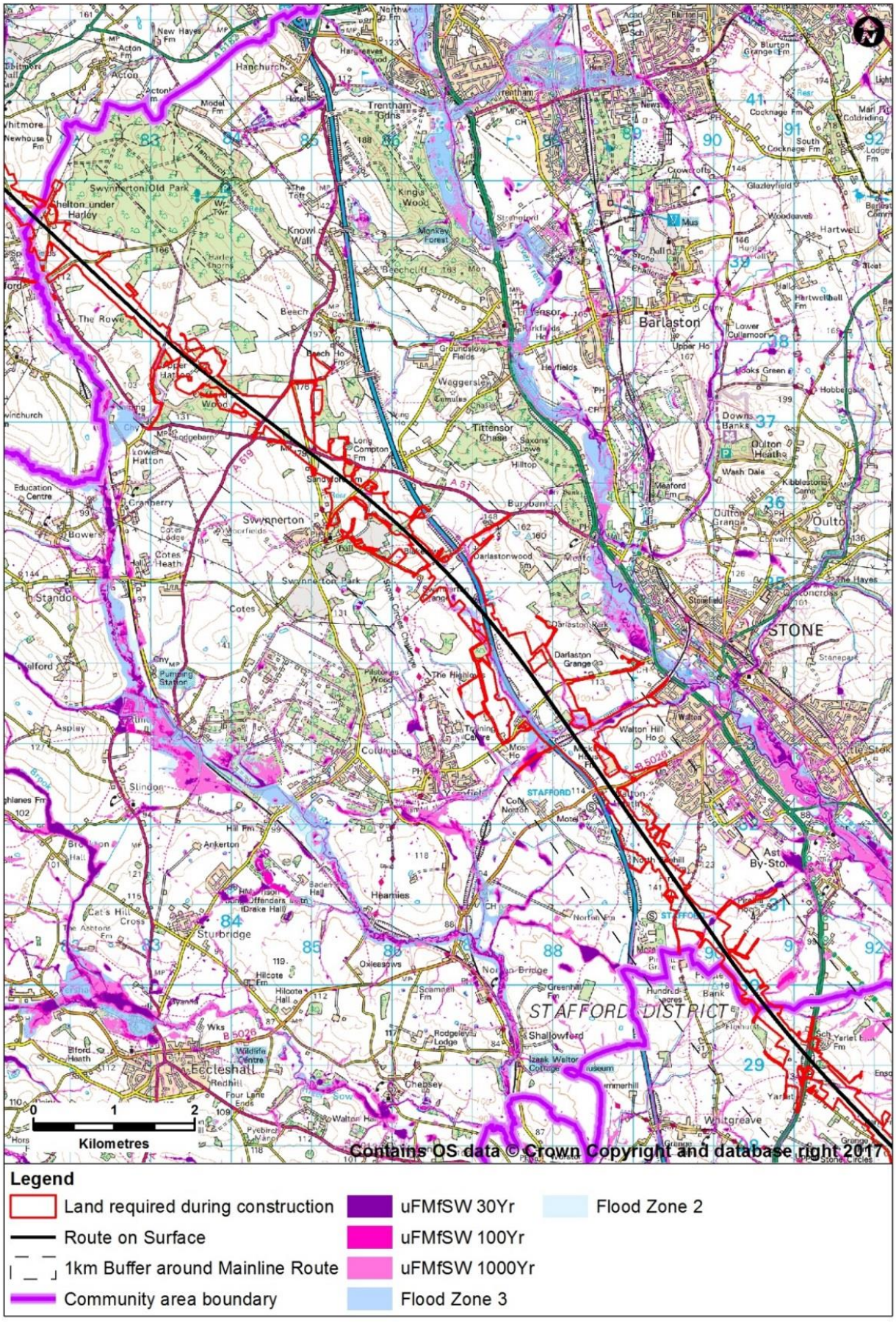
1.3.2 Figure 1 also shows the extent of the land required during the construction of the Proposed Scheme, Environment Agency Flood Zones 2 and 3[2], as well as the areas at risk from surface water flooding. The flood zone information is based on the

[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 a 1 in 100 (1%) or greater annual probability of river flooding

Environment Agency's flood map for planning (rivers and seas) and the updated flood map for surface water (uFMfSW)[3].

[3] 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

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)[4]. 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). Staffordshire County Council (SCC) is the LLFA in the Whitmore Heath to Madeley area. A series of meetings has been held with SCC 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 SCC Preliminary Flood Risk Assessment (PFRA)[5] was published in 2011 and the Local Flood Risk Management Strategy (LFRMS)[6] was published in 2015. SCC LFRMS contains a number of policies related to sustainable development, access to, and maintenance of, ordinary watercourses and the need to consider environmental opportunities that reinforce the objectives of the River Basin Management Plan (RBMP). The Proposed Scheme design has sought to align with these policies where reasonably practicable.

2.2.3 The Local Planning Authorities (LPA) Stoke-on-Trent City Council and Newcastle-under-Lyme Borough Council have produced Strategic Flood Risk Assessments (SFRAs) that cover their administrative boundaries[7,8]. 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

[4] Department for Communities and Local Government (2012), *National Planning Policy Framework*
[5] Royal Haskoning (2011), *Staffordshire County Council Preliminary Flood risk Assessment*
[6] Shropshire and Staffordshire County Council (2015), Shr*opshire and Staffordshire Local Flood Risk Management Strategy*
[7] Halcrow (2008), *Stoke-on-Trent Strategic Flood Risk Assessment*
[8] Halcrow (2008), *Newcastle-under-Lyme Strategic Flood Risk Assessment*

alleviation schemes, and improve flood awareness and emergency planning. The Proposed Scheme design has sought to align with these objectives where reasonably practicable.

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[4]. 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[9] 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. This does not mean that HS2 would be fully operational during such a flood.

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 (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.

3.5 Floodplain storage

3.5.1 Watercourse crossings have been designed to reduce losses of floodplain storage as far as is reasonably practicable. 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.

[9] 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 event, with an allowance for climate change.

3.8 Climate change allowances

General approach

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[10]. 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 Humber river basin district in which the Whitmore Heath to Madeley area lies.

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

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

River basin	Allowance category	Allowance
Humber	H++	65%
	Upper end	50%
	Higher central	30%
	Central	20%

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 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 been classified using Table 2 of the planning practice guidance on flood risk and coastal change[11], which is aligned with the receptor value in the Scope and Methodology Report (SMR)[12] and its Addendum[13].

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

[11] Department for Communities and Local Government (2016), Planning practice guidance and planning system, https://www.gov.uk/guidance/flood-risk-and-coastal-change
[12] Environmental Impact Assessment Scope and Methodology Report, Volume 5: Appendix CT-001-001
[13] Environmental Impact Assessment Scope and Methodology Report, Volume 5: Appendix CT-001-002

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.

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.

3.8.7 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

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

H++ scenarios

3.8.9 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 has used allowances that equate or exceed the H++ value provided in the guidance for peak river flows, which for the Humber catchment is 65%, as indicated in Table 1.

4 Flood risk 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)[14]. 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)[15] 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)[16] has been used to scope surface water flood hazards. Infrastructure failure flood hazards have been scoped using the Environment Agency Risk of flooding from reservoirs national dataset[15]. The British Geological Survey national dataset, areas susceptible to groundwater flooding (AStGWF)[17], 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 aligned with Table 2 of the planning practice guidance on flood risk and coastal changeas set out in Volume 5: Appendix CT-001-001 and CT-001-002.

[14] Highways Agency, *Design for Roads and Bridges*, http://www.standardsforhighways.co.uk/ha/standards/dmrb/
[15] Gov.uk, *Flood map for planning*, https://flood-map-for-planning.service.gov.uk//
[16] 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
[17] British Geological Survey, *Susceptibility to groundwater flooding*, http://www.bgs.ac.uk/products/hydrogeology/groundwaterFlooding.html

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 and its Addendum which are set out in Volume 5: Appendix CT-001-0001 and CT-001-002.

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.

5 Flood risk baseline

5.1 Historical flooding incidents

5.1.1 There are very few historical records of flooding available for the area. However, one location of historical fluvial flooding is identified at Wrinehill Hall associated with Checkley Brook. This is located approximately 400m to the south-east of where the route crosses River Lea and Checkley Brook, at the far northern extent of the community area. The SFRA does not provide further details or information regarding when this event occurred.

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:

- Meece Brook to the south of Whitmore;
- the Upper River Lea at its crossing with the West Coast Main Line (WCML); and
- the Lower River Lea at its confluence with Checkley Brook.

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 assessment of impacts and effects are considered below.

Meece Brook

5.2.3 There are no existing models for Meece Brook, and the Environment Agency flood maps are believed to be derived by National Generalised Modelling (JFLOW). As such, new fluvial hydraulic models of these watercourses have been produced. These models have then been used to determine the flood extent resulting from the 1 in 100 (1%) annual probability flood event with an allowance for climate change and to identify existing receptors that are at potential risk from fluvial 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 downstream (to the south) of the Proposed Scheme where it crosses Meece Brook, are listed below:

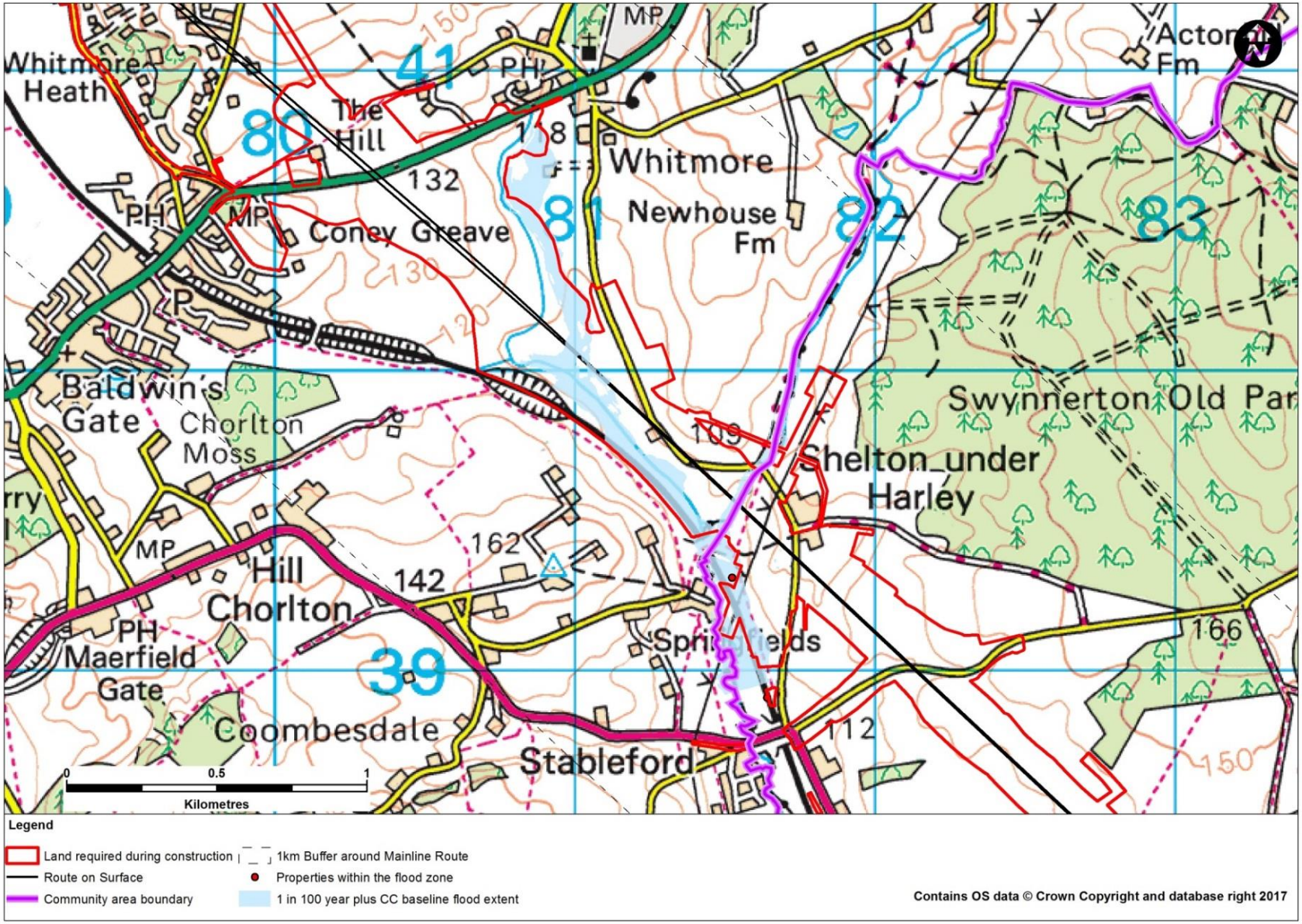
- Stableford Caravan Park (highly vulnerable);
- A51 London Road (essential infrastructure); and

5.2.6 The receptors and their vulnerability located upstream (to the north) of the Proposed Scheme where it crosses Meece Brook are listed below:

- residential properties at Whitmore - more vulnerable; and
- Whitmore cricket club pitch - water compatible.

5.2.7 A climate change allowance comprising a 50% increase in peak river flows has been adopted at this crossing.

Figure 2: Fluvial flood risk associated with Meece Brook near Whitmore



River Lea

5.2.8 There are no existing models for the River Lea, and the Environment Agency flood maps are believed to be derived by National Generalised Modelling (JFLOW). As such, new fluvial hydraulic models of these watercourses have been produced. These models have then been used to determine the flood extent resulting from the 1 in 100 (1%) annual probability flood event with an allowance for climate change and to identify existing receptors that are at potential risk from fluvial flooding.

5.2.9 Figure 3 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.

5.2.10 The receptors and their vulnerability located upstream (to the south) of the Proposed Scheme where it crosses the River Lea are listed below:

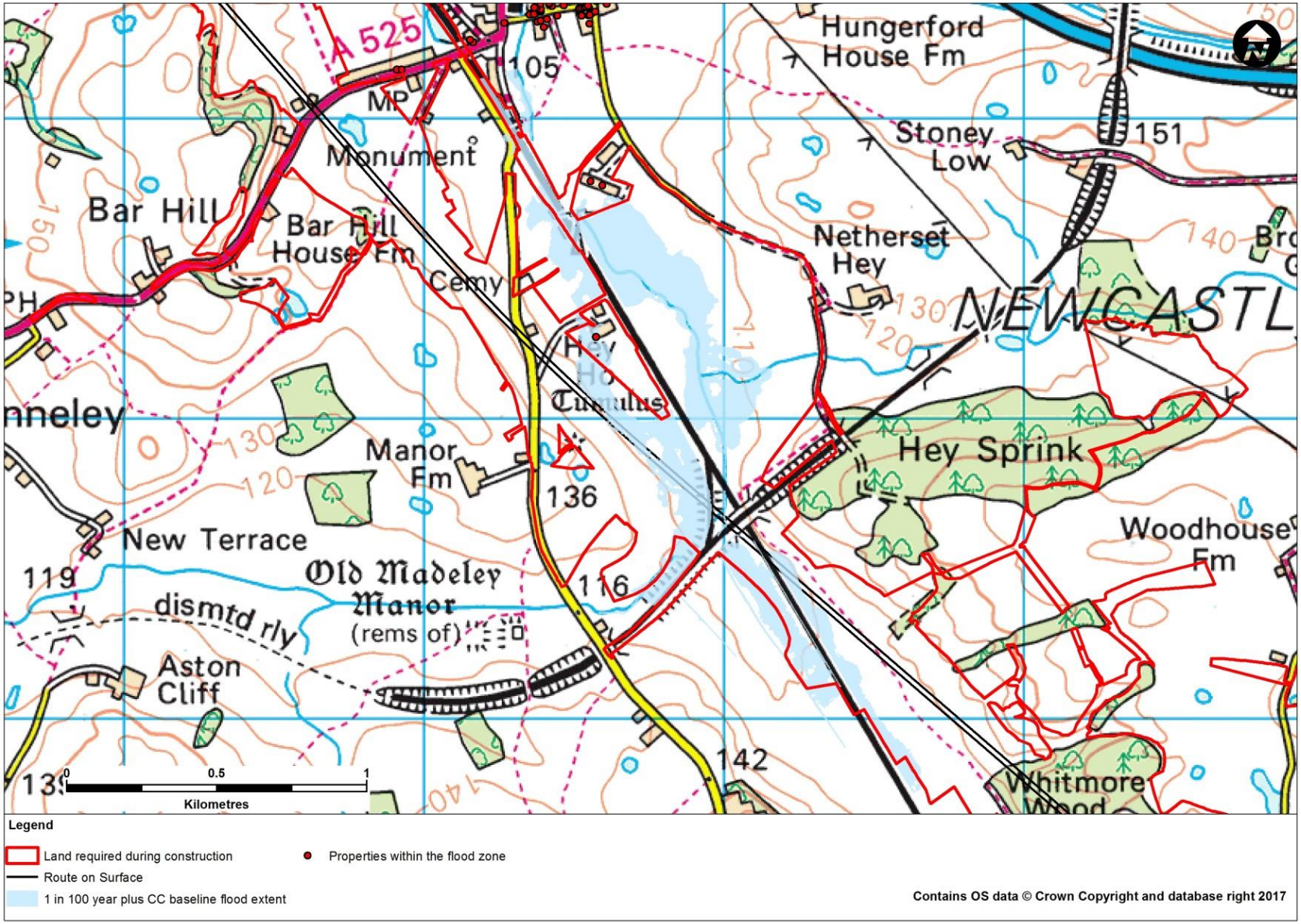
- WCML (essential infrastructure);
- Madeley Chord railway line (essential infrastructure); and
- Manor Road (less vulnerable);

5.2.11 The receptors and their vulnerability located downstream (to the north) of the Proposed Scheme where it crosses the River Lea are listed below:

- Netherset Industrial Estate (more vulnerable);
- WCML (essential infrastructure); and
- residential properties at Madeley (more vulnerable).

5.2.12 A climate change allowance comprising a 50% increase in peak river flows has been adopted at this crossing.

Figure 3: Fluvial flood risk associated with River Lea near Madeley



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 extent with climate change allowance.

5.3.2 As presented in Figure 4 and Figure 5, the following (with relative vulnerabilities) receptors are at risk of flooding from surface water:

- residential properties at Stableford, Whitmore and Madeley (more vulnerable);
- the A53 Whitmore Road at Baldwin Gate (essential infrastructure);
- the WCML (essential infrastructure); and
- Manor Road, Bower End Lane, and the A525 Bar Hill Road to the west of Madeley (less 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 catchment areas are all less than 5km^2.

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

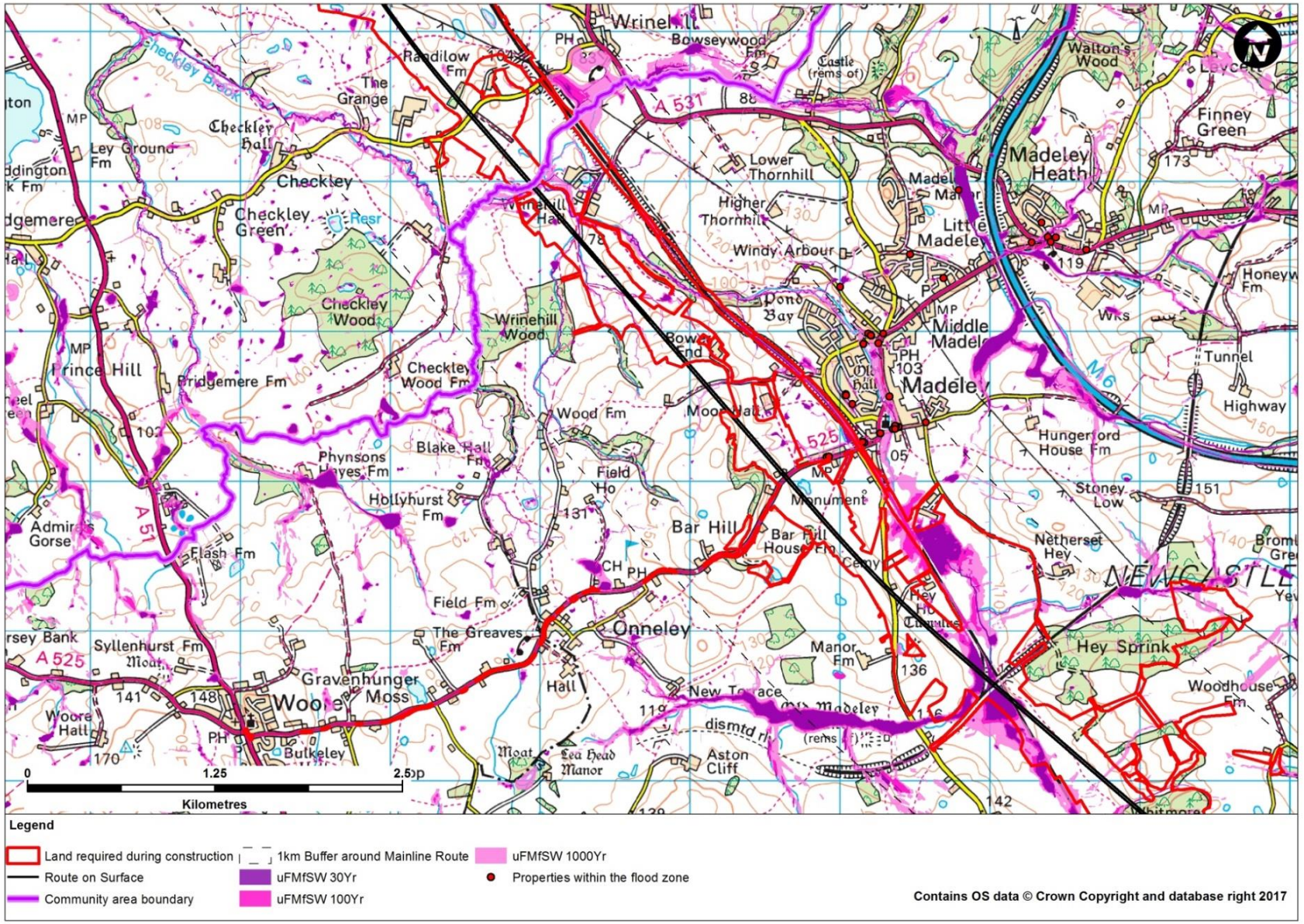
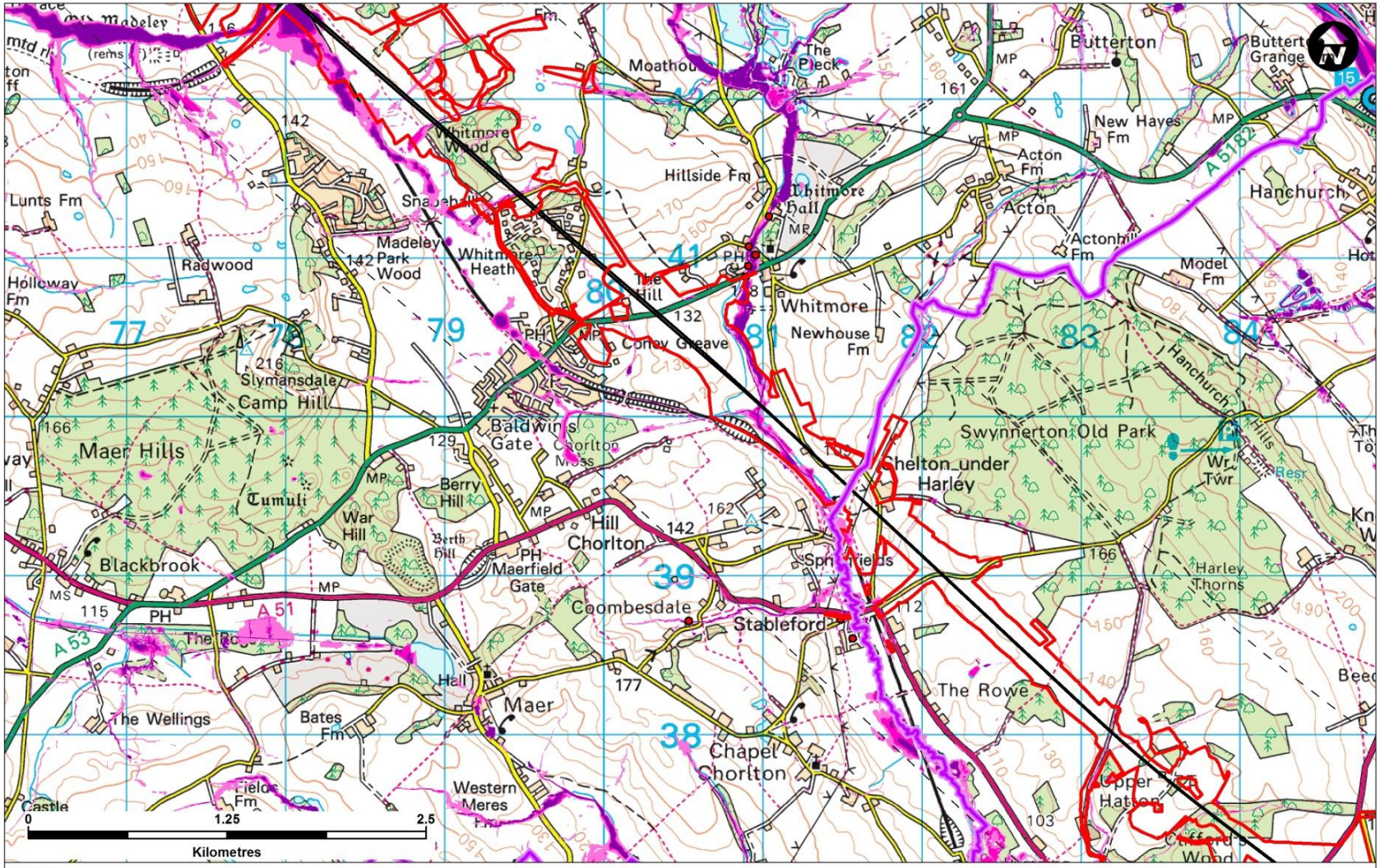


Figure 5: Surface water flood risk (southern part of the study area)



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 Newcastle-under-Lyme Borough Council area generally follow the main river networks, specifically the River Lea, Checkley Brook and Meece Brook. In the south of the study area, around Baldwin's Gate, permeable strata of the Sherwood Sandstone Group outcrop and the potential for groundwater flooding in this area is likely to be associated with potential discharge of water from this aquifer. Areas elevated above approximately 130 to 140mOD (Ordnance Datum) are shown to have limited susceptibility to, or are not considered to be prone to, groundwater flooding.

5.4.3 The SFRA does not report any historic groundwater flooding incidents within the study area.

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. The Environment Agency's Flood risk from reservoirs mapping indicates that there are no reservoirs with a volume in excess of 25,000m^3 within the Whitmore Heath to Madeley area. However, the following smaller man-made features have been identified within the community area as being a potential source of flood risk:

- Cudmore Fisheries - these ponds are located approximately 2km to the north of the route, to the north of Whitmore. The ponds feed into Meece Brook downstream, which is crossed by the route south of Whitmore. The ponds are unlikely to pose a risk to the route, however, given that the Proposed Scheme will be raised on a viaduct across Meece Brook;
- Madeley Pond - located towards the northern end of the community area, in the centre of Madeley. The pond is located approximately 1km to the east of the route, impounding a stretch of the River Lea. The River Lea is crossed by the route approximately 2.8km downstream of Madeley Pond. The pond would not pose a risk to the route, because the Proposed Scheme will be raised on a viaduct across the River Lea;
- Madeley Manor Lake - located roughly 2.2km to the east of the route, towards the far northern extent of the community area, north of Madeley. The lake impounds a tributary of Checkley Brook. Checkley Brook is crossed by the route approximately 3.5km downstream of the lake. The lake is unlikely to pose a risk to the route, however, given that the Proposed Scheme will be raised on a viaduct across Checkley Brook; and

- major water supply pipelines and sewerage (foul and surface water) infrastructure have been identified and are accounted for on the Proposed Scheme drawings.

5.5.2 There are no canals located within the community 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
Meece Brook	Stableford Caravan Park	1 in 100 (1%) annual probability flood extent with allowance for climate change	Essential infrastructure	50%
	A51 London Road			
	Whitmore cricket club pitch			
	Residential properties at Whitmore			
River Lea	WCML	1 in 100 (1%) annual probability flood extent with allowance for climate change	Essential infrastructure	50%
	Manor Road			
	Netherset Industrial Estate			
	Residential properties at Madeley			
Surface water flow paths	Residential properties at Stableford, Whitmore and Madeley	uFMfSW 1% Annual Exceedance Probability	Essential infrastructure	40%
	A53 Whitmore Road at Baldwin's Gate			
	WCML			
	Manor Road, Bower End Lane, and the A525 Bar Hill Road at to the west of Madeley			

6 Flood risk impacts and effects

6.1 Rivers and ordinary watercourses

Viaducts

6.1.1 The Proposed Scheme within the Whitmore Heath to Madeley area includes crossings of two watercourses on viaducts: Meece Brook and River Lea.

6.1.2 The hydraulic models of these watercourses have been used in the design and assessment of the Proposed Scheme in the following ways:

- to define the 1 in 100 (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 in 100 (1%) annual probability flood extent including an allowance for climate change, where reasonably practicable; 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 assessments undertaken of these watercourses can be found in the supporting hydraulic modelling technical appendices (BID[1]). The results of these assessments are reported below for each watercourse in turn.

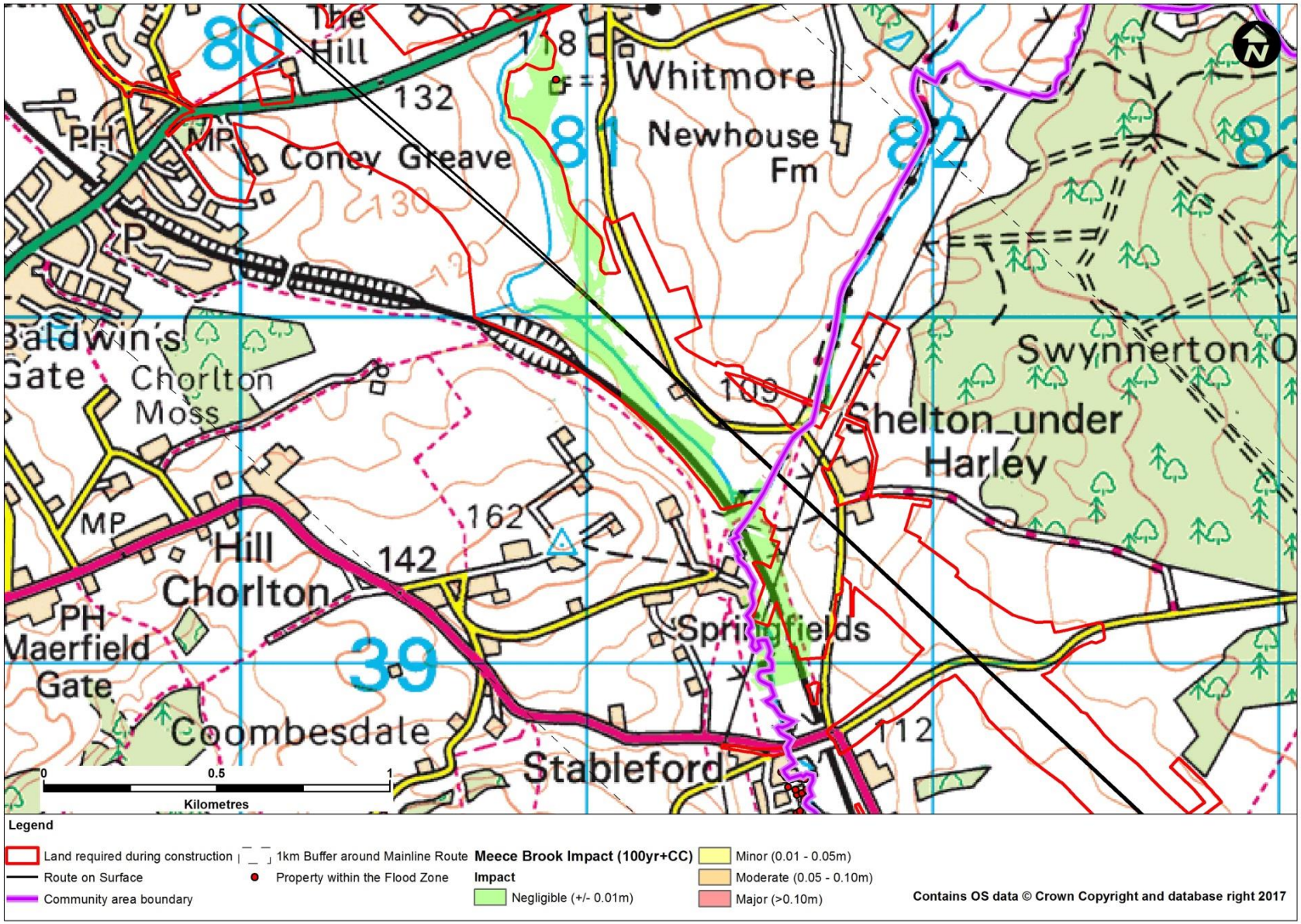
Meece Brook

6.1.4 As shown in Figure 6, the results of the hydraulic model study of Meece Brook indicate that the piers of the proposed viaduct will cause a negligible change in the predicted 1 in 100 (1%) plus climate change peak flood level, as indicated by the green shading on the figure. The land inundated by flood water is an area of undeveloped land, immediately upstream of the proposed viaduct, and so the effect will not be significant.

6.1.5 A small realignment of Meece Brook channel is required to accommodate a proposed pier. By providing a channel that matches existing dimensions and capacity the flood risk characteristics of the local area will remain unchanged. This feature is included in the fluvial hydraulic model of Meece Brook.

6.1.6 The Environment Agency's Flood map for planning (rivers and sea) indicates that a number of residential caravan properties are potentially at risk of flooding downstream of the viaduct at Stableford Caravan Park. The hydraulic model used in this flood risk assessment does not extend downstream to the caravan park, however as there is no change in modelled flood levels at the model boundary, it can be concluded that there will be no change in peak flood levels at the caravan park.

Figure 6: Post development flood risk on Meece Brook

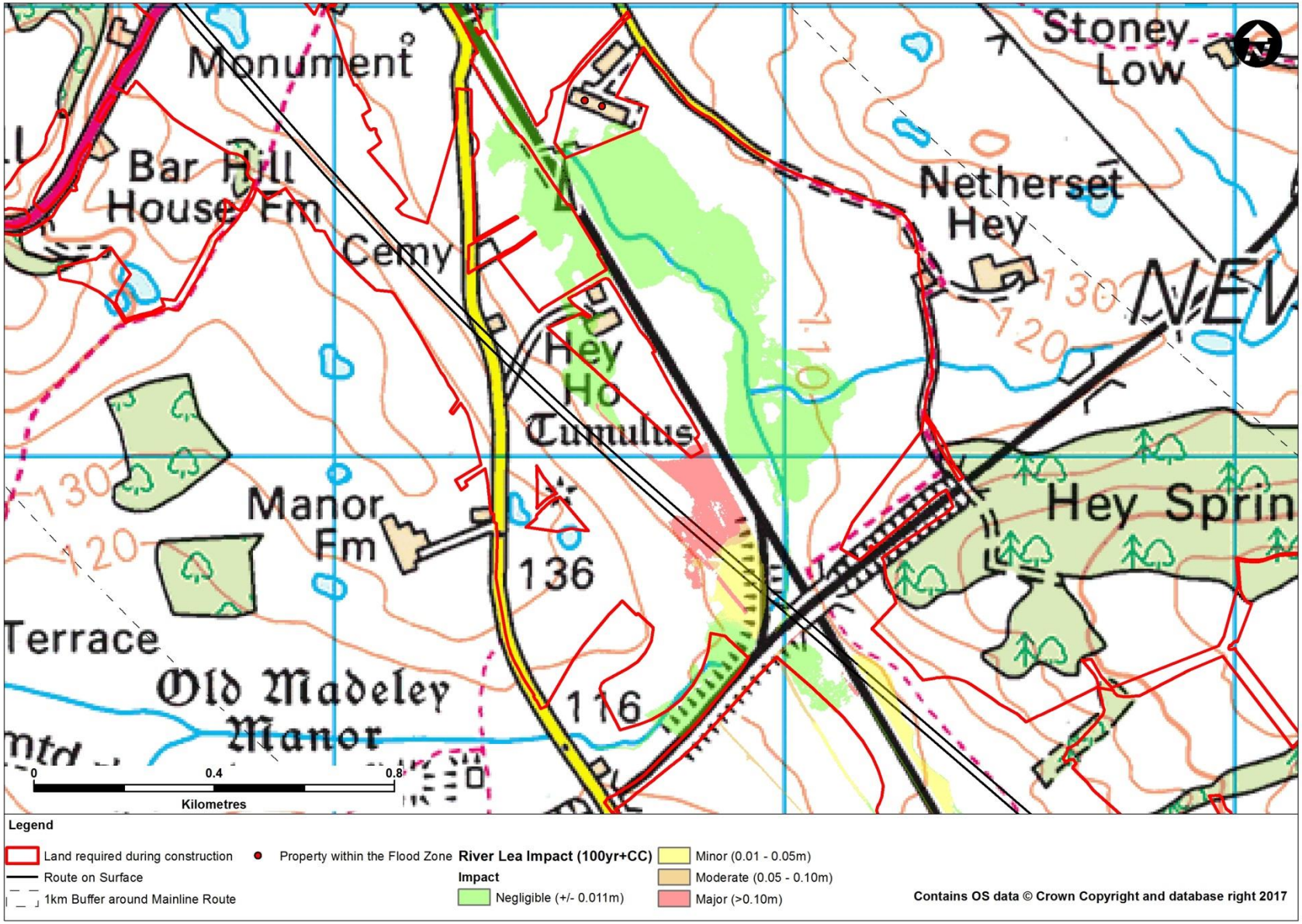


River Lea

6.1.7 Figure 7 shows that the construction of the River Lea viaduct incorporating embedded mitigation measures (flood relief diversion channels to the east and west of the route, the River Lea Flood Culvert and replacement floodplain storage) will result in a major increase in the 1 in 100 (1%) annual probability plus climate change flood level in the immediate vicinity of the viaduct. This increase in flood level affects a small area of agricultural land which is considered less vulnerable, and thus a moderate value receptor. As such, the impact of this increase in flood level is deemed to be moderate adverse, which is significant.

6.1.8 The additional mitigation proposed to address this significant effect is outlined in Section 7.

Figure 7: Post development flood risk on River Lea near Madeley



Culverts and channel diversions

6.1.9 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.

6.1.10 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 the existing gradient of the watercourse using OS Mapping and LiDAR data;
4. determination of the likely roughness characteristics of the proposed culverts; and
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, whilst ensuring a minimum of 300mm freeboard to the pipe soffit above this design flood level.

6.1.11 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	Estimated 1 in 100 (1%) annual probability peak flow (m^3/s)	Climate change allowance	Culvert dimensions (m)	Culvert capacity (m^3/s)
Ordinary watercourse south of Whitmore Wood	Snape Hall Road drop inlet culvert	0.05	40%	1.35x1.35	1.41
Ordinary watercourse north of Whitmore Wood	Whitmore Wood culvert	0.18	20%	1.35x1.35	1.41
Tributary of River Lea, south of Lea / Checkley confluence.	Wrinehill Wood culvert	0.04	40%	1.35x1.35	1.41
Tributary of River Lea, south of Lea / Checkley confluence.	Madeley Bridleway 2 accommodation underbridge[18]	0.99	70%	1.35x1.35	2.36

[18] This culvert is incorporated into the Checkley Brook model which is reported in the South Cheshire area Flood risk assessment

6.1.12 Table 5 illustrates that the minimum culvert dimension proposed, 1.35m x 1.35m, has ample capacity to convey the predicted peak flows. By following this design approach the flood risk to the receptors identified is unchanged.

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

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

- tunnel portal access road off Snape Hall Road, affecting a tributary of an ordinary watercourse south of Whitmore Wood;
- balancing pond access located adjacent to the Whitmore Wood culvert, affecting a tributary of an ordinary watercourse south of Whitmore Wood; and
- Madeley North Auto Transformer Station (ATS) access road.

6.1.15 The design of culverts required to convey water under highways and permanent access roads will follow the procedures outlined in Section 6.1.10. 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 6.1.12 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 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	Estimated 1 in 100 (1%) annual probability peak flow (m^3/s)	Climate change allowance	Culvert/channel dimensions (m)	Channel capacity (m^3/s)
Surface water flow path	Dab Green drop inlet culvert	0.06	40%	1.35 x 1.35	1.41
Surface water flow path	Madeley Park culvert	0.06	40%	1.35 x 1.35	1.41
Surface water flow path	Drummer Stile inverted siphon	0.24	40%	Two box culverts, each 1.35 x 1.35	1.41
Surface water flow path	Barhill aqueduct	0.07	40%	1.5 x 2.9 (open channel)	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 5.3 is unchanged. As such the magnitude of flood risk to these receptors is deemed 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 Whitmore Heath to Madeley area, there are two tunnels: the Whitmore Heath tunnel and the Madeley tunnel. In the vicinity of the Whitmore Heath tunnel groundwater levels are not know. Based on conservative assumptions, groundwater levels are expected to be below the base of the tunnel, except potentially in the northern section of the twin bored tunnel and the northern porous portal, in the Salop Formation Secondary A aquifer and the Sherwood Sandstone Group Principal aquifer. If the tunnel 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 Madeley tunnel intersects the Sherwood Sandstone Group Principal aquifer, the Mercia Mudstone Group Secondary B aquifer and the Halesowen Formation Secondary A aquifer. The porous portal at the southern end of the tunnel is also supported by a retaining wall. Although the AStGWF shows that there is limited potential for groundwater flooding at this location, there is limited information about groundwater levels in this area and there is potential for the tunnel and portal to create a barrier to groundwater flow. If the features intersect groundwater there is potential for local changes to groundwater level, and therefore potential to increase risk of groundwater flooding. Although there are no receptors in the vicinity of the tunnel, ground investigation is required to confirm groundwater levels and ground conditions, and drainage systems will be designed to reduce any apparent risks.

6.3.5 Whitmore Wood retaining wall will run along the eastern side of the Whitmore North cutting. Although the AStGWF shows that there is little or no potential for groundwater flooding at this location, there is limited information about groundwater levels in this area and there is potential for the retaining wall to create a barrier to groundwater flow in the Salop Formation Secondary A aquifer. Ground investigation is required to confirm groundwater levels and ground conditions, and drainage systems will be designed to reduce any apparent risks.

6.3.6 In the area of the borrow pit, west of Netherset Hey Farm, groundwater levels in the Glaciofluvial Deposits Secondary A aquifer are expected to be close to ground level and groundwater flow is expected to follow the natural topographic gradient towards the River Lea. 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 The Environment Agency's 'Flood risk from reservoirs' mapping indicates that there are no reservoirs with a volume in excess of 10,000m^3, in the vicinity of the route of the Proposed Scheme within the Whitmore Heath to Madeley area.

6.4.2 Other infrastructure that has the potential to cause flooding, in the event of a failure of an impounding structure or a pipeline include: ponds associated with Cudmore fisheries, Madeley Pond and Madeley Manor Lake and existing utilities such as major water supply pipelines and sewerage (foul and surface water) infrastructure.

6.4.3 The Cudmore fisheries are located in the upper reaches of Meece Brook, upstream of the Meece Brook Viaduct. Given the elevation of the viaduct, and the relatively small volume of the ponds, it is considered unlikely that the construction of the Proposed Scheme could have any effect on the resulting flood risk from the fisheries.

6.4.4 Madeley Pond and Madeley Manor Lake are located upstream of the Checkley Brook viaduct. Given the elevation of the viaduct, and the relatively small volume of the pond, it is considered unlikely that the construction of the Proposed Scheme could have any effect on the resulting flood risk.

6.4.5 Major water supply pipelines and sewerage (foul and surface water) infrastructure have been identified and are accounted for on the Proposed Scheme drawings CT-05 and CT-06 available in the Volume 2 Map Book. This infrastructure has been identified and diverted where appropriate. Measures will be taken to safeguard the local receptors during this diversion process.

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

6.4.7 The surface water management of runoff from the Proposed Scheme has been designed in the following manner:

- existing surface water catchments and the existing receptor identified;
- appropriate runoff rates calculated;
- changes to these catchment imposed by the Proposed Scheme determined; and
- a surface water management network incorporating attenuation basins has been designed to ensure that surface water discharges to existing receptors are not increased up to the 1 in 100 (1%) annual probability rainfall event with an allowance for climate change.

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 flood, 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 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.

7.1.2 The detailed hydraulic analysis of the River Lea indicates that the Proposed Scheme has potential to lead to a moderate adverse significant effect related to flood risk downstream of the viaduct. Additional flood risk management measures in this area could include:

- additional topographic survey of structures, river channel and floodplain;
- verification of culvert locations connecting floodplain areas either side of the WCML with Network Rail; and
- development of the hydraulic design with the aim of reducing impacts on flood levels as far as is reasonably practicable.

7.1.3 The above activities will be undertaken in close consultation with the Environment Agency, the LLFA and, if any residual effects are identified, with the affected landowners, including Network Rail. The aim will be to ensure that no parties are affected by unacceptable increases in flood risk.

7.1.4 Where inverted siphons are to be constructed on surface water flow paths with no permanent flow, such as at Drummer Stile inverted siphon, clearance of the siphon will be incorporated into the HS2 asset maintenance programme to ensure its long term operation.

8 Summary of significant flood risk effects

8.1.1 The potential for moderate adverse significant effects on flood risk has been identified associated with the construction of the River Lea viaduct.

8.1.2 The additional measures outlined in Section 7 will focus on ensuring that this localised effect is mitigated to as low a level as is reasonably practicable in consultation with landowners and the Environment Agency.

9 Conclusions

9.1.1 The analysis undertaken indicates that 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 and additional mitigation options at the River Lea viaduct crossing will be undertaken at the detailed design stage to determine the optimal solution for reducing the increase in peak flood level in the vicinity of this watercourse crossing.

10 References

British Geological Survey, *Susceptibility to groundwater flooding*. Available online at: http://www.bgs.ac.uk/products/hydrogeology/groundwaterFlooding.html.

Department for Communities and Local Government (2016), *Planning practice guidance and planning system*. Available online at: https://www.gov.uk/guidance/flood-risk-and-coastal-change.

Environment Agency, *Flood risk assessments: climate change allowances*. Available online at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

Gov.uk, *Flood map for planning*. Available online at: https://flood-map-for-planning.service.gov.uk/.

Gov.uk, *Long term flood risk information*. Available online at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?easting=402498&northing=282043&address=100070518535.

Halcrow (2008), *Stoke-on-Trent Strategic Flood Risk Assessment.*

Halcrow (2008), *Newcastle-under-Lyme Strategic Flood Risk Assessment.*

Highways Agency, *Design for Roads and Bridges*. Available online at: http://www.standardsforhighways.co.uk/ha/standards/dmrb/.

HS2 Ltd (2017), High Speed Two Phase 2a: West Midlands to Crewe, Background Information and Data, *CA3: Stone and Swynnerton, Hydraulic modelling report - Meece Brook*, (BID-WR-004-008). Available online at: www.gov.uk/HS2.

HS2 Ltd (2017), High Speed Two Phase 2a: West Midlands to Crewe, Background Information and Data, *CA4: Whitmore Heath to Madeley, Hydraulic modelling report - River Lea,* (BID-WR-004-009). Available online at: www.gov.uk/HS2.

HS2 Ltd (2017), High Speed Two Phase 2a: West Midlands to Crewe, Background Information and Data, *CA5: South Cheshire, Hydraulic modelling report - Checkley Brook,* (BID-WR-004-010). Available online at: www.gov.uk/HS2.

HS2 Ltd (2012), High Speed Two (HS2) Appraisal of Sustainability Options Report: Final, Available on line at: 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.

Royal Haskoning (2011), *Staffordshire County Council Preliminary Flood risk Assessment.*

Shropshire and Staffordshire County Council (2015), *Shropshire and Staffordshire Local Flood Risk Management Strategy.*

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