A428 Black Cat to Caxton Gibbet improvements

TR010044

Volume 6

6.3 Environmental Statement

Appendix 13.4: Flood Risk Assessment

Planning Act 2008

Regulation 5(2)(e)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

26 February 2021

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

A428 Black Cat to Caxton Gibbet improvements
Development Consent Order 202[ ]

Appendix 13.4: Flood Risk Assessment

Regulation Number	Regulation 5(2)(e)
Planning Inspectorate Scheme Reference	TR010044
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Author	A428 Black Cat to Caxton Gibbet improvements Project Team, Highways England

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Rev 1	26 February 2021	DCO Application

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Executive Summary

This Flood Risk Assessment (FRA) has been undertaken to assess the risk of flooding to and from the A428 Black Cat to Caxton Gibbet improvements (the Scheme). The study area includes key features of the water environment interacting with and located along the Scheme route and their associated watercourse catchments. The River Great Ouse is the only main watercourse within the study area. Sources of flood risk within the study area are fluvial, surface water, groundwater, sewers and artificial sources both during construction and operational phases.

To better understand the fluvial flood risk posed to the study area and to assess the potential impacts to and from the Scheme, hydraulic modelling has been undertaken for the main River Great Ouse and several ordinary watercourses for a range of return periods. The proposed changes to local topography that have the highest risk of surface water/ pluvial flooding, as a result of the Scheme, include water crossing locations at Rectory Farm, Hen Brook and South Brook. Additional 2D hydraulic modelling has been completed to supplement initial 1D modelling, to better assess the impact of the Scheme on both fluvial and surface water flood risk in this area. A groundwater risk assessment was undertaken to assess the impact of the Scheme to groundwater, including the potential risk of groundwater flooding. In addition to hydraulic modelling assessments, the remainder of the study area was assessed as to its existing level of risk and potential sensitivity of change as a result of the Scheme.

Several key Scheme elements (during operational and construction stages) were identified as having the potential to influence flood risk within the study area. These features were assessed against the identified baseline flood risk to determine the potential impact *to* and *from* the Scheme. Only an assessment of flooding from the construction stage was completed, since any flood risk to the construction stage will be suitably mitigated by the Principal Contractor, as set out in the Outline Water Management Plan (OWMP) (Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**), in accordance with Requirement 4 in Schedule 2 of the draft Development Consent Order (DCO) **[TR010044/APP/3.1]**.

Requirement 3 of the draft DCO **[TR010044/APP/3.1]** requires preparation of a Second Iteration Environmental Management Plan, which will also include consideration of flood risk. Current Environment Agency fluvial flood extents for Main River (River Great Ouse) have been generated using a detailed 1D-2D hydraulic model. For some of the ordinary watercourses 2D only models have been used to generate flood extents however these lack detail with regards to channel geometry. Therefore, in order to create a refined representation of flood risk within the areas of interest and facilitate a more robust assessment of the Scheme, site specific hydraulic models were created for the ordinary watercourses, and hydrological assessments undertaken. For Main River, the model representing the River Great Ouse has been updated to meet the requirements of this project. The Environment Agency and Local Lead Flood Authorities (LLFA) have been consulted throughout the hydraulic modelling process, including obtaining their agreement to the methodology for hydrological analysis and hydraulic modelling, and procuring their review and approval of modelling outputs. As such, in consultation with the relevant flood authorities, the hydraulic modelling outputs inform the Environment Agency Flood Zones for the purposes of this FRA.

Most of the study area is within Flood Zone 1 (low probability), except where it traverses river channels, where areas of Flood Zone 2 and 3 are present. The baseline modelling flood extents for the watercourses largely coincide with the corresponding Flood Zones produced by the Environment Agency.

The majority of surface water flood risk in the study area, illustrated by the Environment Agency Flood Risk from Surface Water data, is categorised as 'Very low'; with some small 'pockets' of 'Low', 'Medium' and 'High' flood risk. These are typically located in areas where the Scheme traverses the ordinary watercourses and where surface water flow paths are impeded by artificial structures.

The additional 1D-2D hydraulic modelling at Hen Brook, Rectory Farm (also known as Rectory Farm Brook) and South Brook will assist in understanding and managing any surface water flood risk at these topographical low-lying areas within the Scheme.

The risk of groundwater flooding is considered to be low in the vast majority of the study area with the only exception the western part of the Scheme where the potential for groundwater flood risk is considered to be high due to the shallow groundwater conditions and the potential for groundwater-surface water interaction in the floodplain of the River Great Ouse.

The risk of flooding from artificial sources and snowmelt is low.

The assessment of flood risk during the operational stage of the Scheme has concluded that with design mitigation, the risk to the Scheme from fluvial, pluvial, groundwater and sewer flooding would be low.

The assessment of flood risk from the operational stage of the Scheme has concluded that with design mitigation, the risk to other receptors from fluvial, pluvial, groundwater and sewer flooding would be low. Modelling undertaken shows that there would be no increase in flood risk to properties as a result of the Scheme.

The assessment of flood risk from the construction stage of the Scheme has concluded that, with design mitigation, the risk to other receptors from fluvial, pluvial and sewer flooding would be low. The temporary and/or permanent construction features (such as cuttings, piling and other associated structures) could alter groundwater level and flow regime resulting in potential flood risk, however; following implementation of mitigation measures, the risk to receptors from groundwater as a result of the Scheme would be low.

1 Introduction

1.1 Commission

1.1.1 This Flood Risk Assessment (FRA) has been prepared to support the Development Consent Order (DCO) application for the A428 Black Cat to Caxton Gibbet improvements (the Scheme).

1.1.2 The Scheme comprises a new 10 mile dual 2-lane carriageway from west of the A421/A1 Black Cat roundabout through to east of the A428/A1198 Caxton Gibbet roundabout.

1.2 Scope, assumptions and study area location

1.2.1 The aim of this FRA is to assess the flood risk impact of the operational and construction stages associated with the Scheme.

1.2.2 The potential sources of flood risk considered are fluvial, surface water, groundwater, sewers and artificial sources. Tidal flooding has not been considered due to ground levels above predicted future tide levels and distance from coastal regions.

1.2.3 The assessment has included information provided by statutory consultees and stakeholders and has involved extensive liaison with these stakeholders to ensure all flood sources have been adequately considered and assessed.

1.2.4 Section 6 describes the baseline flood risk from all flood risk sources within the study area to receptors.

1.2.5 The following sections address flood risk in the operational and construction stages of the Scheme. For each stage it is defined as:

a. The flood risk *to* the Scheme as a receptor.

b. The flood risk to other receptors, following impact *from* the Scheme.

1.2.6 This is covered in the report as follows:

a. The flood risk *to* the Scheme, once operational, is detailed in Section 7.

b. The flood risk *to* the Scheme, during construction, is to be mitigated by the Principal Contractor, to ensure no significant risk to the Scheme, as set out in the Outline Water Management Plan (OWMP) (Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**), in accordance with Schedule 2 of the draft DCO **[TR010044/APP/3.1]**.

c. The flood risk to other receptors, following impact *from* the Scheme, once operational, is detailed in Section 8.

d. The flood risk to other receptors, following impact *from* the Scheme, during construction, is detailed in Section 9.

1.2.7 Section 10 is a summary of Sections 6 to 9, describing the conclusions of the FRA for identified sources within the study area.

1.2.8 Hydraulic modelling has been undertaken for significant flood risk areas including detailed fluvial modelling for the River Great Ouse, Hen Brook, Rectory Farm (also known as Rectory Farm Brook) and South Brook using 1D-2D models. All other ordinary watercourses which traverse the Scheme have been assessed using 1D only models. This is discussed in more detail within Section 5 of this report.

1.2.9 Baseline and proposed scenarios have been modelled for a range of return periods. The assumptions for the completed hydraulic models are described in the River Great Ouse Hydraulic Modelling Report, Annex A and the Ordinary Watercourses Hydraulic Modelling Report, Annex B of this FRA.

1.2.10 The FRA includes the main features of the water environment crossing the Scheme, and any watercourse catchment extents, within which significant adverse effects may occur, for hydrological assessments and areas to be used for construction works and operational purposes (**Figure 1.1**).

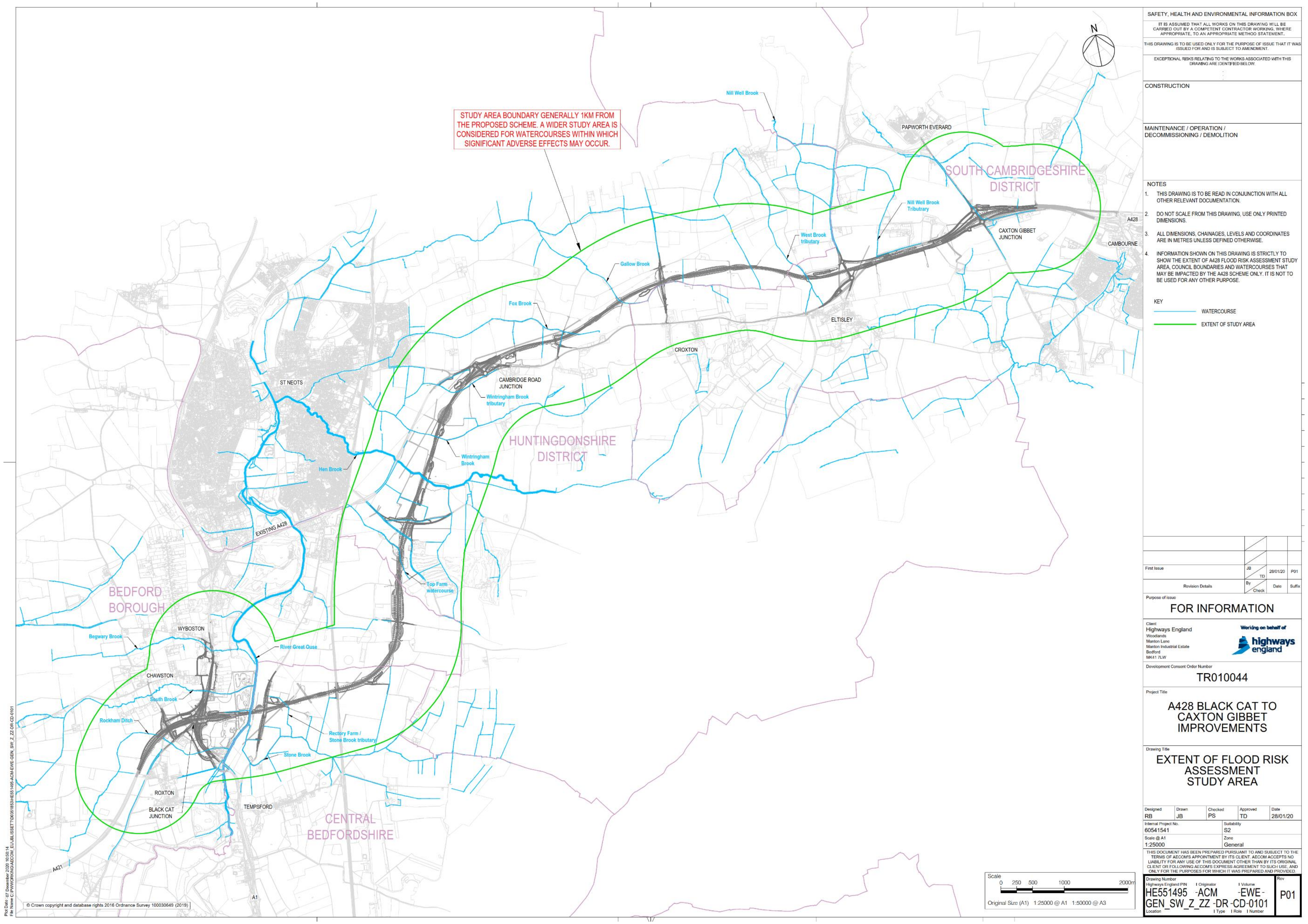

Figure 1.1 Extent of study area

2 Study area hydrological context

2.1 Overview

2.1.1 This section provides a summarised overview of the hydrology and hydrogeology of the study area.

2.1.2 The detailed geological and hydrogeological conditions of the study area are provided in the following chapters of the Environment Statement **Chapter 9 Geology and soils**; **Chapter 13, Road drainage and the water environment** of the Environmental Statement **[TR010044/APP/6.1]**.

2.1.3 A review of the baseline conditions that enabled consideration of the potential impact on groundwater from the Scheme is set out in Section 3 of **Appendix 13.7** - Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**.

2.2 Hydrogeology

2.2.1 The ground elevation across the Scheme area rises from approximately 20m AOD in the vicinity of the Black Cat roundabout, to greater than 50m AOD in the Allington Hill area, before falling again to c. 20m AOD in the floodplains of Hen Brook in the central part of the Scheme. To the east of Hen Brook, the ground level rises gently to greater than 65m AOD in a north / north easterly direction to the eastern end of the Scheme.

2.2.2 British Geological Survey (BGS) Sheets 187(7) and 204(8), Solid and Drift editions, show the geology along the route to comprise clays and mudstones of Jurassic age largely overlain by Glacial Deposits, with Alluvium and River Terrace deposits found in the valleys of the River Great Ouse and Hen Brook.

2.2.3 The aquifers in the superficial deposits are designated as either Secondary A Aquifers or Secondary undifferentiated aquifers. The aquifer in the Alluvium and River Terrace Deposits have been designated by the Environment Agency as Secondary A aquifers that are only able to sustain local abstraction, while the aquifer in the glacial till is designated as a Secondary Undifferentiated aquifer with limited groundwater potential.

2.2.4 A Preliminary Sources Study Report was carried out in 2018, which involved a qualitative assessment of desk study sources to inform the geotechnical risks across the length of the Scheme. This study identified the need for a full intrusive ground investigation along the length of the Scheme to enable geotechnical design to be undertaken.

2.2.5 Ground investigation surveys were undertaken between September 2019 and March 2020.

2.2.6 The ground investigation within the Order Limits confirmed that the geological sequence comprised a variety of superficial deposits overlying the solid geology.

2.2.7 The Superficial Deposits comprise Topsoil, Made Ground, Alluvium, River Terrace Deposits and Glacial Till. The solid geology comprises Oxford Clay Formation over Kellaways Formation in the West and West Walton/Amphill Clay over Kellaways Formation in the East. The Kellaways Formation is present beneath the entire study area.

2.2.8 As part of the ground investigation, groundwater level monitoring has been undertaken showing the variability of the groundwater level along the whole length of the Scheme, including sub-artesian conditions near the existing Black Cat roundabout area.

2.2.9 An assessment of the presence of the groundwater, where the new dual carriageway is in cutting has been completed based on the ground investigation exploratory hole logs and described in **Appendix 13.7** - Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**.

2.3 Hydrology

Rainfall

2.3.1 Rainfall data from the Environment Agency from the station at Great Paxton, located approximately 3.5 kilometres north of the Scheme and from the station at Bourn, approximately 4.8 kilometres south-east of the Scheme, are shown in **Table 2-1**, with an annual average rainfall of between 578.8mm (Great Paxton) and 597.0mm (Bourn).

2.3.2 Monthly average rainfall for the above mentioned stations and the annual average are shown in **Table 2-1**.

Table 2-1 Average rainfall (mm)

Average	Bourn (2003-2020)	Great Paxton (2008-2000)
January	54.6	62.0
February	44.1	43.0
March	37.8	33.1
April	33.4	36.5
May	58.8	53.5
June	48.9	47.0
July	58.9	81.0
August	76.1	86.9
September	44.7	39.4
October	55.4	65.3

Average	Bourn (2003-2020)	Great Paxton (2008-2000)
November	60.7	64.1
December	47.9	53.2
Annual Average	**597.0**	**578.8**

Main watercourse - River Great Ouse

2.3.3 The River Great Ouse, designated as a Main River, flows northwards in the west part of the study area. The Environment Agency has a station located approximately 3.5 kilometres north of the Scheme, at Eaton Socon and a station approximately 2 kilometres south of the Scheme at Roxton, which is the nearest to the study area.

2.3.4 The Environment Agency maximum water levels recorded for River Great Ouse are 15.63m AOD at Eaton Socon station and 17.94m AOD at the Roxton station.

Ordinary watercourses

2.3.5 Several ordinary watercourses are located within the study area as indicated in the following list:

a. Rockham Ditch
b. South Brook
c. Rectory Farm (Stone Brook tributary)
d. Begwary Brook
e. Hen Brook
f. Wintringham Brook
g. Wintringham Brook tributary
h. Fox Brook
i. Gallow Brook
j. West Brook tributary
k. Other smaller Ordinary watercourses include, Rectory Farm (Farm), Nill Well Brook Tributary, Top Farm and Caxton Gibbet drain.

Flood defences

2.3.6 Based on data received from the Environment Agency, no formal flood defences are located within the study area.

2.3.7 The Scheme is not located within an Area Benefitting from Defences as defined by the Environment Agency, therefore, a flood defence failure would not place the Scheme at risk of flooding. No further reference is required for the purpose of this FRA.

3 Scheme description

3.1 Scheme

3.1.1 The purpose of the Scheme is to address the problems of congestion, poor journey time reliability and poor resilience against incidents between the Black Cat and Caxton Gibbet roundabouts. The Scheme seeks to address these problems through construction of a new 10 mile (16 kilometres) dual 2-lane carriageway from the Black Cat roundabout to Caxton Gibbet roundabout, to be known as the A421 (hereafter referred to as the 'new dual carriageway'), and in addition approximately 1.8 miles (3 kilometres) of tie-in works, shown in schematic form in **Figure 3.1** below.

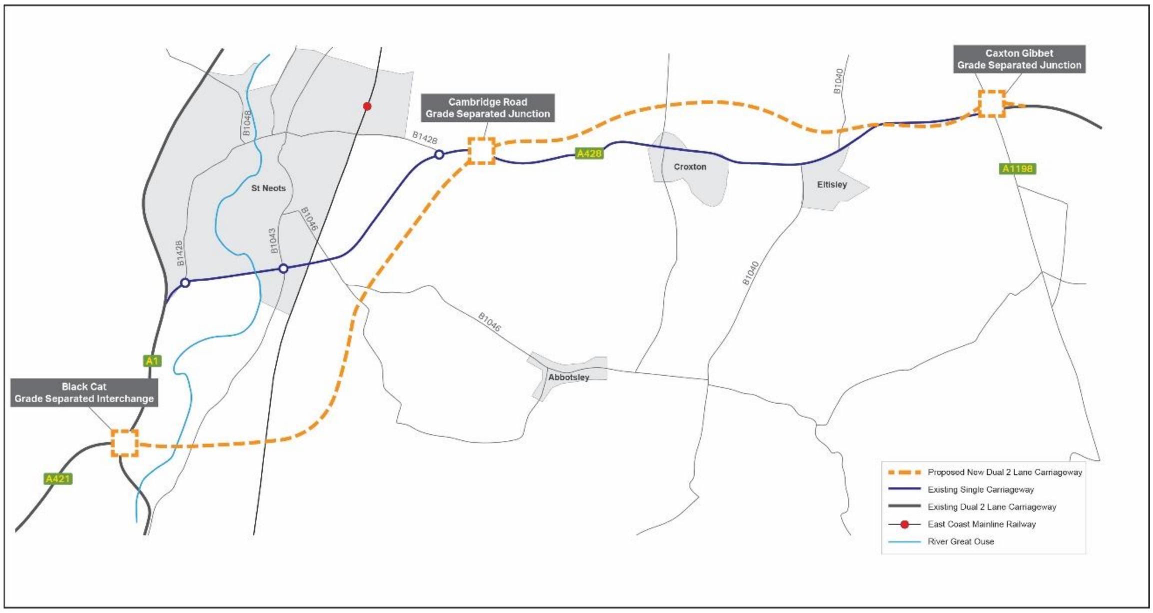

Figure 3.1 The Scheme

3.1.2 The Scheme includes the following components:

a. A new three-level grade separated junction at Black Cat roundabout, with the A1 at the lower level, the new dual carriageway on the upper level and a roundabout between the two at approximately existing ground level. In addition to slip roads a new free flowing link between the A421 eastbound carriageway and the A1 northbound carriageway will also be provided.

b. A new grade separated all movements junction will be constructed to the east of the existing Cambridge Road roundabout to provide access to the new dual carriageway and maintain access to the existing A428.

c. At the Caxton Gibbet roundabout, a new grade separated all movements junction will be constructed, incorporating the existing roundabout on the south side of the new dual carriageway and a new roundabout on the north side. The new dual carriageway will then tie-in to the existing A428 dual carriageway to the east of the new Caxton Gibbet junction.

d. In the vicinity of the new Black Cat junction, direct access onto the A1 from some local side roads and private premises will be closed for safety reasons. A new local road will provide an alternative route. The existing Roxton Road bridge will be demolished and replaced with a new structure to the west to accommodate the realigned A421.

e. New crossings will be constructed to enable the new dual carriageway to cross the River Great Ouse, East Coast Main Line railway, Barford Road, the B1046/Potton Road, Toseland Road and the existing A428 at Eltisley.

f. The existing A428 between St Neots and Caxton Gibbet will be de-trunked and retained for local traffic and public transport with maintenance responsibility transferred to the local highway authorities.

g. An alternative access will be provided to side roads at Chawston, Wyboston and Eltisley.

h. There will be safer routes for walkers, cyclists, and horse riders.

3.2 Operational stage features

3.2.1 The Scheme includes the following key operational stage features that have the potential to impact flood risk:

a. Black Cat Junction upgrades, with the lowering of A1.

b. River Great Ouse viaduct.

c. New Cambridge Junction.

d. New Caxton Gibbet Junction.

e. Floodplain compensation areas.

f. Embankments and cuttings.

g. Landscaping.

h. Provision of new utilities.

Black Cat Junction upgrades, with the lowering of A1

3.2.2 As described in Section 3.2, the new Black Cat Junction would result in an increase in impermeable area which could potentially increase surface water flood risk and the lowering of the A1 will increase groundwater flood risk. The Scheme is to minimise groundwater ingress and to ensure that surface water is managed effectively and sustainably.

River Great Ouse viaduct

3.2.3 The Scheme would cross the River Great Ouse and its floodplain. The new viaduct, located east of the existing Black Cat roundabout, would be a 6-span structure, comprising of two decks each carrying the new eastbound and westbound carriageways. Each deck would be supported by in-situ reinforced concrete abutments and intermediate piers comprising four circular reinforced concrete columns. The piers and adjoining embankments have been designed and located to avoid the river channel and provide minimal obstruction of floodplain flows during both construction and operation, nevertheless, the introduction of piers and embankment into the floodplain has potential to interrupt flood flows and create a local backwater.

New Caxton Gibbet and Cambridge Junctions

3.2.4 The new Cambridge and Caxton Gibbet junctions would result in an increase in impermeable area which could potentially increase surface water flood risk. The Scheme is to incorporate appropriate design mitigation to ensure that surface water flood risk does not increase as a result of new junctions, as detailed within **Appendix 13.3** (Road Drainage Strategy Report) of the Environment Statement Appendices **[TR010044/APP/6.3]**.

Floodplain compensation areas

3.2.5 Where the Scheme is located within a floodplain, flood compensation is required in order to provide, level for level, volume for volume compensation for the displacement of floodplain storage as a result of the Scheme. Floodplain compensation areas will be built in advance of the Scheme features for which they are required.

3.2.6 The design incorporation of floodplain compensation areas and the hydraulic modelling undertaken to ensure correct functionality are detailed in Annex A for the River Great Ouse and in Annex B of this FRA for the ordinary watercourses.

Embankments and cuttings

3.2.7 The Scheme would include the introduction of embankments or cuttings to integrate the new road alignment into the existing landscape. Adjustments to the land profile to facilitate the creation of embankments and cuttings have the potential to change the catchment characteristics, such as altering surface water overland flow paths.

Landscaping

3.2.8 The landscape design for the Scheme consists of varying depths of fill and re-soiling along the route. These changes include landscaping associated with the implementation of embankments and cuttings, along with larger landscape areas for screening or habitat creation. Permanent topographic changes following embankment creation have the potential to impact flood risk by altering flow paths.

3.2.9 Some landscape areas would have varying depths of topsoil and there is a possibility that this topsoil could affect the conveyance of surface water flows in these areas.

Provision of new utilities

3.2.10 Construction of the Scheme is likely to require the diversion, relocation or protection of approximately 80 existing utility assets including water, wastewater, electricity, gas and telecommunications. These are described in detail within **Chapter 2, The Scheme** of the Environmental Statement **[TR010044/APP/6.1]**.

3.2.11 The relocation of an existing CLH oil pipeline crossing the River Great Ouse floodplain and protection of an existing Cadent NGT gas main, southwest of the existing Black Cat roundabout, , are in an area at low risk of surface water flooding and high risk of fluvial flooding (Flood Zone 3). Flood mitigation for utility works is to be managed by the utility companies, where located within floodplains. The presence of underground structures (foundations or cables) could affect groundwater flows to the River Great Ouse.

3.3 Temporary construction features

3.3.1 The flood risk could be influenced by a number of construction features listed below:

a. River Great Ouse span pier cofferdams.

b. River Great Ouse working platforms.

c. Storage of materials.

d. CLH temporary bridge.

3.4 Design philosophy

3.4.1 For the purpose of mitigating flood risk, the design of the Scheme has been influenced by key considerations described in this section.

Watercourse crossings

3.4.2 A number of design influences were incorporated in relation to the watercourse crossings. The River Great Ouse viaduct is proposed to be a 6-span structure with the location and orientation of the piers and foundations optimised to minimise obstruction of overland directional flow within the floodplain.

Road drainage

3.4.3 The Drainage Strategy Report (DSR) for the Scheme (**Appendix 13.3** of the Environmental Statement Appendices **[TR010044/APP/6.3]**) describes the design philosophy implemented in the design, aimed at managing surface water runoff to minimise flood risk. Runoff from events, up to and including the 1% annual exceedance probability plus climate change allowance, are managed by incorporating attenuation features. Sustainable Drainage Systems (SuDS), as detailed in the DSR, have been incorporated in the Scheme's design, in accordance with CIRIA SuDs manual (C753), Design Manual for Roads and Bridges (DMRB) and planning policy requirements.

Design standard

3.4.4 To minimise flood risk, the Scheme’s design incorporates current design standards and climate change allowances, as described in Section 3.4.3 and Section 4.

4 Policy context and consultation

4.1.1 The following sections summarise the planning policy and regulatory framework that has a direct influence on the structure and content of this FRA.

4.2 National planning policy context

National Policy Statement for National Networks (NPSNN)

4.2.1 The NPSNN (Ref 4-1) is the primary national policy document that will guide decision making on the application. Sections 4 and 5 of the NPSNN, set out policies to guide how DCO applications will be decided and how impacts of national networks infrastructure should be considered.

4.2.2 Paragraphs 5.90 - 5.115 state that the Secretary of State for Transport should be satisfied that flood risk will not be increased elsewhere and should only consider development appropriate in areas at risk of flooding where it can be demonstrated that: the most vulnerable development is located in areas of lowest flood risk unless there are overriding reasons to prefer a different location; development is appropriately flood resilient and resistant, including safe access and escape routes where required; that any residual risk can be safely managed, including by emergency planning; and that priority is given to the use of SuDs. Applications for projects should be accompanied by an FRA to assess all risks of flooding and take climate change into account.

4.2.3 In preparing an FRA an applicant should:

a. Consider the risk of all forms of flooding arising from the project (including in adjacent parts of the United Kingdom), in addition to the risk of flooding to the project, and demonstrate how these risks will be managed and, where relevant, mitigated, so that the development remains safe throughout its lifetime.

b. Take the impacts of climate change into account, clearly stating the development lifetime over which the assessment has been made.

c. Consider the vulnerability of those using the infrastructure including arrangements for safe access and exit.

d. Include the assessment of the remaining (known as ‘residual’) risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the particular project.

e. Consider if there is a need to remain operational during a worst-case flood event over the development’s lifetime.

f. Provide the evidence for the Secretary of State to apply the Sequential Test and Exception Test as appropriate.

National Planning Policy Framework (NPPF)

4.2.4 The NPPF (Ref 4-2) published in 2012 and last updated in June 2019, is supported by the Planning Policy Guidance (PPG) (Ref 4-3), an online resource first published in March 2014 and updated regularly.

4.2.5 The NPPF and PPG must be considered in the preparation of local and neighbourhood plans and are a material consideration in planning decisions.

4.2.6 The NPPF and PPG recommend that Local Plans should be supported by a Strategic Flood Risk Assessment (SFRA) and develop policies to manage flood risk from all sources, taking account of advice from the Environment Agency and other relevant flood risk management bodies, such as LLFAs and internal drainage boards. Local plans should apply a sequential, risk-based approach to the location of development to avoid, where possible, flood risk to people and property and manage any residual risk, taking account of the impacts of climate change, by:

a. Applying the Sequential Test.

b. Applying the Exception Test, if necessary.

c. Safeguarding land from development that is required for current and future flood management.

d. Using opportunities offered by new development to reduce the causes and impacts of flooding.

e. Seeking opportunities to facilitate the relocation of existing development, including housing, to more sustainable locations where climate change is expected to increase flood risk.

4.3 Strategic flood risk assessments

Bedford Borough Council Level 1 Strategic Flood Risk Assessment

4.3.1 The SFRA (Ref 4-4) produced in 2015, examines the planning policies and historical flood events data for Bedford Borough. The document provides modelled flood outlines, historic flood extents, spot flood locations and identifies all sources of flood risk.

4.3.2 As indicated in section 4.3 and Appendix A – Figure A1 of the SFRA, the main source of flood risk within Bedford Borough is fluvial flooding from the River Great Ouse. Wyboston, located within the study area of this FRA, is identified as a key settlement area at risk from fluvial flooding from the River Great Ouse.

4.3.3 Locations with the greatest number of Anglian Water flooding records are localised in the centre of the borough, based on the SFRA section 4.4, outside of the study area of this FRA. Appendix A - Figure A2 of the SFRA, shows the sewer flooding records.

4.3.4 Based on the section 4.5 and Appendix A – Figure A3 of the SFRA, there are no key settlement areas at risk of surface water flooding within the study area.

4.3.5 The SFRA Appendix A – Figure A4 identifies Areas Susceptible to Groundwater Flooding (AStGWF dataset – see Section 6.5) as a strategic scale map showing groundwater flood areas on a 1 kilometre square grid. The areas adjacent to the River Great Ouse, from the Black Cat roundabout to St Neots, in the east of the borough, are shown with >=75% susceptibility to groundwater flooding. The dataset shows that groundwater susceptibility for the Little Barford area is < 25% and for Top Farm is >=25% and lower than 50%.

Central Bedfordshire Council Level 1 Strategic Flood Risk Assessment

4.3.6 The SFRA (Ref 4-5) produced in 2017, provides an assessment of the risk of flooding in areas under the authority of the Central Bedfordshire Council (CBC).

4.3.7 Tempsford is the only parish in the district of Central Bedfordshire located in the vicinity of the Scheme. At Station Road, there are isolated areas with a small amount of flood risk from surface water. The groundwater susceptibility is between 25% and below 75%, based on the AStGWF dataset (see Section 6.5).

4.3.8 Table 7-4 of the SFRA indicates that, for Tempsford, only the areas south of Station Road and west of the A1 are at any significant risk of fluvial flooding from the River Great Ouse. This area may be affected by reservoir inundation from the Great Barford Flood Alleviation – West and East reservoirs. Some records indicate historical flooding from the River Ivel (1937, 1947 and 1998) and an unknown source in 1998.

Cambridge and South Cambridgeshire Level 1 Strategic Flood Risk Assessment

4.3.9 The SFRA (Ref 4-6) developed in 2010 covers flood risk in the administrative areas of South Cambridgeshire District Council (SCDC) and Cambridge City Council (CCC).

4.3.10 Historical flooding information is provided in Table 4A and the figures in Appendix B of the SFRA. Flood locations and flood outlines are specified for different sources: fluvial; ground water; pluvial and sewer flooding.

4.3.11 Figure 3.1 of Appendix B shows some localised sewer and pluvial flood events in Croxton and Eltisley, within the study area of this FRA. The figure also indicates historical flood outlines for the River Great Ouse catchment from 1947, 1998 and 2001, with the highest flooding recorded in 1947.

Huntingdonshire District Council Level 1 and 2 Strategic Flood Risk Assessment

4.3.12 The SFRA for Huntingdonshire (Ref 4-7) was undertaken in 2017 and provides a description of the flood risk from various sources.

4.3.13 The historical flood events relevant to the county have been considered in the overall FRA. Hen Brook, Fox Brook and the River Great Ouse flooded St Neots in 1993, 1998 and 2001; surface water flooding was also recorded. The Wintringham Brook watercourse, part of the study area, flooded some proprieties in St Neots in 2001. Other locations with associated fluvial flood risk from the River Great Ouse catchments and other sources of risk are identified in Table 6-3 of the SFRA. The risk of flooding from the Grafham Water reservoir, located approximately 12 kilometres away from the Scheme, does not extend to the study area of this FRA.

4.3.14 Groundwater susceptibility (AStGWF dataset – see Section 6.5), provided in Appendix F of the SFRA, varies across the district areas relevant to the Scheme, however it is predominantly lower than 25% apart from areas around Cambridge Road junction, where it is s indicated on the dataset to be >75% .

Bedford Borough Council, Central Bedfordshire Council and Milton Keynes Council Preliminary Flood Risk Assessment (PFRA)

4.3.15 The PFRA aims to provide a high-level overview of flood risk from all sources of flooding within the local area, including the consideration of surface water, groundwater, ordinary watercourse and canals, for both historical and future instances.

4.3.16 The 2011 PFRA (Ref 4-8) provides large scale data on proprieties at risk of flooding from different sources. Figures 5.2 and 5.4 define the susceptibility to groundwater flooding on a 1 kilometre square grid (AStGWF dataset – see Section 6.5), with areas around Black Cat predominantly having over 75% susceptibility, on the basis of geological and hydrogeological conditions as indicated in the dataset and shown in the PFRA. The PFRA report does not provide any additional information to identify risks of flooding within or near the study area.

Cambridgeshire County Council Cambridgeshire Preliminary Flood Risk Assessment

4.3.17 The PFRA informs the preparation of Local Flood Risk Management Strategies in line with the Flood and Water Management Act 2010.

4.3.18 The 2011 PFRA (Ref 4-9) offers an overview of the most significant past flood events (from 1947 to 2001) with numbers of proprieties affected in Cambridgeshire. The main sources of flood were Fluvial Main River Watercourses as well as Ordinary Watercourses. Snow melt is mentioned as a cause of the widespread flooding in 1947. The report refers to the Great Ouse Catchment Flood Management Plan (Ref 4-10) and identifies St Neots as an area susceptible to Surface Water Flooding.

4.3.19 The high-level data available in the PFRA does not provide specific reference to the flood risk in the study area of this FRA.

Catchment Flood Management Plan

4.3.20 Catchment Flood Management Plans (CFMPs) are the Environment Agency's high-level strategic plans for the sustainable management of flood risk at a large catchment-scale. The plan assesses the size, nature and distribution of current and potential future flood risk. From the CFMP assessments long-term flood risk management policies are created to provide an indication of who is responsible and the types of responses required, in order to meet those policies that have been identified.

4.3.21 The Great Ouse CFMP (2011) (Ref 4-10) defines six flood risk management policy options and assigns a vision and preferred policy option for each of the eleven sub-regions within the Great Ouse catchment.

4.4 Flood risk management strategies

Bedford Borough Council Local Flood Risk Management Strategy

4.4.1 The 2011 strategy (Ref 4-11) is a key requirement from the Flood and Water Management Act 2010. The document is aimed at better understanding and managing flood risk. It sets out the legislative context and a clear understanding of flood management roles and responsibilities.

4.4.2 Fluvial flooding is the main historical flood source. The impacts include not only water volume but also water quality, as a result of pollutants contaminating run-off from Combined Sewer Overflow surcharge. Chapter 3.7 of the strategy provides a summary of historical flooding events within the Borough.

4.4.3 The future risk of flooding is covered in chapter 3.8 highlighting the importance of resilience to climate change impacts and key considerations in line with the NPPF to prevent new developments from increasing flood risk. The Council's commitment for the management of rainwater and surface water, by ensuring that all major developments incorporate Sustainable Drainage Systems (SuDS), to replicate natural drainage and adapt to climate change, with the objective to reduce the risk of flooding, is also indicated within the strategy.

Central Bedfordshire Local Flood Risk Management Strategy

4.4.4 The strategy (Ref 4-12) was developed in 2014 and later updated in 2016, conforming to the Flood and Water Management Act 2010, which established the Central Bedfordshire Council as a Lead Local Flood Authority (LLFA).

4.4.5 It provides a framework for flood risk management and identifies areas vulnerable to different types of flooding. It specifies the requirement for any new development to incorporate SuDS. The responsibilities for each authority in Central Bedfordshire are clearly outlined and objectives for managing local flood risk are defined.

4.4.6 The Central Bedfordshire Local Flood Risk Management Strategy does not identify any specific risk of flooding to the study area of this FRA.

Cambridgeshire's Local Flood Risk Management Strategy

4.4.7 This strategy (Ref 4-13) has been developed in accordance with the Flood and Water Management Act 2010 and it clarifies roles and responsibilities for local flood risk. It sets out objectives for Cambridgeshire such as understanding and managing flood risk, ensuring appropriate development and improving flood prediction, warning and post flood recovery.

4.4.8 Section 2.2 of the strategy notes the large-scale flood events between 1947 and 2015 that affected Cambridgeshire, from a combination of flooding from various sources, including main rivers, surface water, sewer flooding and ordinary watercourses.

4.4.9 The strategy describes the Surface Water Management Plan for Cambridgeshire, undertaken in 2010 and revised in 2014, which investigates different types of flooding, including data from historical flooding information provided by stakeholders and members of the public. The assessment identified numerous areas, called 'wet spots', at risk of varying levels of surface water flooding by considering how a community would be affected in the event of a flood. St Neots is the only wet spot in the proximity of the study area of this FRA.

4.4.10 As noted in section 5.2 of the strategy, the council's planning system should maximise opportunities for sustainable development and adaptation to climate change.

4.5 Other relevant policy and guidance

Design Manual for Roads and Bridges

4.5.1 Guidance outlined in the Design Manual for Roads and Bridges (DMRB) (Ref 4-14) was refenced during the analysis of flood risk for watercourse crossings such as culverts and bridges.

4.5.2 The DMRB LA113 Road drainage and the water environment table 3.70 defines the importance of water environment attributes as the vulnerability of the receptors (i.e. highly vulnerable) and table 3.71 defines the magnitude of a change impact on an attribute. When combining the importance and magnitude from these tables the potential significance of effect can be defined in accordance with DMRB LA104 Environmental assessment and monitoring table 3.8.1 Significance Matrix. The assessment of significant effects on flood risk sources during the construction and operation of the Scheme is undertaken within the Environment Statement (refer to section 14.9 of **Chapter 13, Road drainage and the water environment** of the Environmental Statement **[TR010044/APP/6.1]**).

4.6 Consultation

4.6.1 The following parties have been consulted throughout the development of the Scheme:

a. Environment Agency

b. Bedford Group of Internal Drainage Board (IDB)

c. Bedford Borough Council - Lead Local Flood Authority (LLFA)

d. Central Bedfordshire Council – LLFA

e. Cambridgeshire County Council - LLFA

f. South Cambridgeshire District Council – LLFA

g. Anglian Water

4.6.2 Under the Flood and Water Management Act 2010, the Environment Agency has direct responsibility for the mitigation and remediation of flood damage for main rivers. The designated IDB and LLFAs for this Scheme are responsible for the management of local flooding from surface water, groundwater and ordinary watercourses. Anglian Water is the sewage undertaker in the vicinity of the Scheme.

4.6.3 Discussion and agreement of approaches and methodologies has been undertaken with the Flood Risk Management Authorities to ensure that the assessment of flood risk within the study area is appropriate for the nature and scale of the Scheme, through the A428 Flood Risk and Water Management Technical Working Group (TWG) meetings and associated correspondence.

4.6.4 The responses to the statutory consultation that was carried out between June and July 2019, along with separate discussions with stakeholders, have been considered to identify issues raised regarding road drainage and the water environment. The Consultation Report **[TR010044/APP/5.1]** sets out how there has been due regard to comments raised during statutory consultation.

4.7 Climate change

4.7.1 The Environment Agency published climate change guidance in February 2016 (Ref 4-15), which was updated in 2019. The guidance indicates that climate change is likely to increase river flows, sea levels, rainfall intensity, and wave height and wind speed. The 2019 information and advice has therefore been used to complete this FRA and engagement with the Environment Agency will continue as this Scheme progresses through the DCO process.

Peak River Flow Allowances by River Basin District

4.7.2 The peak river flow allowances show the anticipated changes to peak flow by river basin district. The range of climate change allowances is based on percentiles (**Table 4-1**). A percentile is a measure used in statistics to describe the proportion of possible scenarios that fall below an allowance level. The 50th percentile is the point at which half of the possible scenarios for peak flows fall below it and half fall above it:

a. Central allowance is based on the 50th percentile.

b. Higher central is based on the 70th percentile.

c. Upper end is based on the 90th percentile.

4.7.3 At the central allowance, 50% of the possible scenarios fall below this value. So, if the higher allowance is a 25% increase in peak flow, then current scientific evidence suggests that there is a 50% chance that peak flows will increase by less than this value, but there remains a 50% chance that peak flows will increase by more.

4.7.4 At the higher central allowance, 70% of the possible scenarios fall below this value. So, if the higher allowance is a 35% increase in peak flow, then current scientific evidence suggests that there is a 70% chance that peak flows will increase by less than this value, but there remains a 30% chance that peak flows will increase by more.

4.7.5 At the Upper End, 90% of the possible scenarios fall below this value. So, if the higher allowance is a 65% increase in peak flow, then current scientific evidence suggests that there is a 90% chance that peak flows will increase by less than this value, but there remains a 10% chance that peak flows will increase by more.

Table 4-1 Climate change allowance for the Anglian River Basin District

River Basin District	Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Anglian	Upper End	25%	*35%*	***65%***
	Higher Central	15%	20%	35%
	Central	10%	15%	25%

Peak river flow allowances for different assessments

4.7.6 For FRAs, the "flood risk vulnerability classification", Table 2 in the NPPF Planning Practice Guidance for Flood Risk and Coastal Change Guidance (Ref 4-16) for the type of development and the "flood zone" (Table 1 in the guidance) should be used to decide which peak river flow allowances (allowance category) to use based on the lifetime of the Scheme. The indications from Environment Agency's climate change guidance (Ref 4-15) are shown in **Table 4-2**. The Scheme assessed in this FRA is considered essential infrastructure.

Table 4-2 Peak river flow allowances based on flood risk vulnerability classification and flood zone

Flood Zone 2 or 3a
Essential infrastructure – use the upper end allowance Highly vulnerable infrastructure – use higher central and upper end allowances to assess a range of allowances (note – development should not be permitted in flood zone 3) More vulnerable – use the higher central and upper end allowances to assess a range of allowances Less vulnerable – use the central and higher central allowances to assess a range of allowances Water compatible – use the central allowance
Flood Zone 3b
Essential infrastructure – use the upper end allowance Highly vulnerable – development should not be permitted More vulnerable – development should not be permitted Less vulnerable – development should not be permitted Water compatible – use the central allowance

Peak river flow allowances for the Scheme

4.7.7 It is assumed that the lifetime of the Scheme is 100 years therefore the peak river flow climate change allowances for the lifetime of the Scheme should be assessed as shown in **Table 4-3** below.

Table 4-3 Peak river flow allowances for the Scheme hydraulic modelling

Criteria	Scheme
River Basin District	Anglian
Flood Zone	1, 2 and 3 (including 3b functional floodplain)
Flood Risk Vulnerability Classification	Essential Infrastructure (transport link)
Lifetime of Scheme	100 years
Climate Change Allowance used	Upper End Allowance (65%)

Floodplain storage compensation

4.7.8 The assessment of the floodplain storage compensation is based on Environment Agency's climate change guidance (Ref 4-15). The affected land uses define the level of allowance with the higher central allowance (35%) being indicated for most cases, while ensuring no flooding affects sensitive receptors with the upper end allowance (65%).

Peak rainfall intensity allowance

4.7.9 Increased rainfall affects river levels and land and urban drainage systems. **Table 4-4** below shows anticipated changes in extreme rainfall intensity in small and urban catchments. For FRAs, both the central and upper end allowances need to be assessed to understand the range of impact.

Table 4-4 Peak rainfall intensity allowance

Applies across all of England	Total potential change anticipated for 2010 to 2039	Total potential change anticipated for 2040 to 2069	Total potential change anticipated for 2060 to 2115
Upper End	10%	20%	40%
Central	5%	10%	20%

5 Flood risk assessment methodology

5.1 Methodology approach

5.1.1 The approach to the FRA is based on the Source-Pathway-Receptor model in accordance with the NPPF emphasis for the need for this approach.

5.1.2 The Source-Pathway-Receptor model firstly identifies the causes or 'sources' of flooding to and from a development. The identification is based on a review of local conditions and consideration of the effects of climate change using Environment Agency guidance. The nature and likely extent of flooding arising from any one source is considered, e.g. whether such flooding is likely to be localised or widespread.

5.1.3 The presence of a flood source does not always infer a risk. It is the exposure pathway or the 'flooding mechanism' that determines the risk to the receptor and the effective consequence of exposure. For example, sewer flooding does not necessarily increase the risk of flooding unless the sewer is local to the site and groundwater levels encourage surcharged water to accumulate.

5.1.4 The varying effect of flooding on the 'receptors' depends largely on the sensitivity of the target. Receptors include any people or buildings within the range of the flood source, which are connected to the sources of flooding by a pathway.

5.1.5 For there to be a flood risk, all elements of the model (a flood source, a pathway and a receptor) must be present. Furthermore, effective mitigation can be provided by removing one element of the model, for example by removing the pathway or receptor.

5.1.6 As outlined in Section 1.2.6, this FRA assesses the risks of all relevant forms of flooding *to* and *from* the Scheme, once operational, but only assesses the risk of flooding *from* the construction of the Scheme, since any risk *to* the construction works is to be mitigated by the Principal Contractor, to ensure no significant risk to the Scheme, as set out in the Outline Water Management Plan (OWMP), Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**.

5.2 Source-pathway-receptor

5.2.1 The potential flood sources which could be impacted from the construction stage and operational stage features of the Scheme are identified as:

a. Fluvial
b. Surface water
c. Groundwater
d. Sewers
e. Artificial sources (such as reservoirs)

5.2.2 The pathways present or potentially impacted by the Scheme are identified as:

a. Floodplain inundation due to the river levels exceeding the channel capacity.

b. Overland flow paths (fluvial and surface water).

c. Flow of groundwater through the superficial deposits.

5.2.3 The receptors of concern include any people or buildings within the range of the flood source, which are connected to it by a pathway.

5.2.4 The groundwater source-pathway-receptor approach is set out in Section 5 of **Appendix 13.7** - Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**.

5.3 Modelling

5.3.1 Hydraulic modelling was undertaken to support the development of the FRA to provide a more detailed understanding of the baseline flood risk within the study area. The outputs were used to augment existing Environment Agency flood risk mapping and to assess the potential impacts of flood risk to and from the Scheme.

5.3.2 Further detail on the hydraulic modelling methodology for the River Great Ouse (Main River) is available in Annex A, while the methodology for the ordinary watercourses is available in Annex B of this FRA. A detailed hydrology study undertaken to support the hydraulic modelling of the ordinary watercourses is available in Annex C.

Fluvial

5.3.3 Two different hydraulic modelling approaches were used for different watercourses to assess fluvial flood risk. Some watercourses have been modelled using a 1D only approach, while some have been updated to a linked 1D-2D FMP-TUFLOW model. Each approach was determined on its merits to appropriately assess the required watercourse and was supported by consultation with the Environment Agency.

5.3.4 The 1D only hydraulic models provide a simple representation of hydraulics, directly representing flows in the streamwise direction only. Whilst 1D only modelling approaches cannot accurately reproduce complex floodplain flows, simple floodplain flows and storage can be represented through inclusion of extended cross sections and reservoir/ attenuation units. Data requirements are modest, with the primary data input being constituted by a cross sectional survey including significant structures, in order to represent the geometry of the river channel and floodplain. 1D models provide key outputs such as levels, flows, flow volumes and velocities.

5.3.5 A linked 1D-2D FMP-TUFLOW hydraulic model allows a more detailed assessment of the interaction of the channel (1D) and inundation on the floodplain (2D). When the capacity of the 1D channel is exceeded, water spills into the 2D model. The grid based 2D model allows water to propagate across the floodplain according to complex topography and other factors such as surface roughness. This facilitates a more accurate calculation of flood depths and extents that are used to generate map outputs.

5.3.6 The choice between the two approaches was a function of the watercourse characteristics such as catchment area and peak flow, along with the complexity of hydraulics near the Scheme elements. In addition, the flood hazard posed by the watercourse along with the presence of vulnerable receptors close to the modelled reach, and therefore the overall risk to people and property, was also factored into the selection of approach for each model.

5.3.7 As a Main River with a large catchment, surrounded by sensitive receptors, the River Great Ouse has been modelled using a linked (existing) 1D-2D FMP-TUFLOW approach. Hen Brook and South Brook have larger catchments and peak flows than other ordinary watercourses included within the study area, while Rectory Farm presents a complex hydraulic scenario. As such, the Hen Brook, South Brook and Rectory Farm watercourses were also modelled using a linked 1D-2D FMP-TUFLOW approach.

5.3.8 The remaining watercourses identified in Section 2.10, which generally have smaller catchments and peak flows, have been represented using a 1D only FMP or Micro Drainage approach. It was initially agreed with the Environment Agency and LLFAs that 1D modelling was required for ordinary watercourses. However, based on the characteristics and hydraulics associated with these watercourses, combined with the location of the Scheme, a 1D only FMP or Micro Drainage approach was considered more appropriate than a desk study approach.

5.3.9 It should be highlighted that given the substantial variation in characteristics of the ordinary watercourses at the location where the Scheme crosses each catchment, it was not considered a technical requirement to use the equivalent methodology to reach the same level of robustness in Scheme assessment for each watercourse. Rather, the approach adopted for the hydraulic modelling assessment for each watercourse has been selected according to several factors including the watercourse characteristics and required outcomes for the assessment. The modelling approach adopted for the River Great Ouse is detailed within Annex A while the approach for the ordinary watercourses is detailed in Annex B of this FRA.

5.3.10 The peak river flow climate change allowances adopted to consider the impacts on future fluvial flood risk were agreed with the Environment Agency at the outset of the project. For the River Great Ouse the 1% AEP design event including an allowance for climate change (1% AEP +35% increase in peak flows) has been simulated for the baseline and proposed operational stage scenarios. The allowance of +35% corresponds to the ‘Higher Central’ allowance for the Anglian river basin district. Simulated sensitivity runs with a +65% climate change allowance, corresponding to the ‘Upper End’ allowance, were also modelled as agreed with the Environment Agency.

5.3.11 For the ordinary watercourses, the climate change allowances within the Environment Agency's 'Flood Risk Assessments: Climate Change Allowances" were applied. According to this guidance the 'Upper End' allowance should be considered for essential infrastructure in Flood Zones 2 and 3 (unless an alternative approach is agreed with the Environment Agency Environment Agency) and therefore +65% was applied to the 1% AEP event (based on the 'Upper End' allowance for the Anglian river basin district). It is considered that this represents a conservative scenario and provides an additional level of climate change resilience associated with the Scheme implementation. The +35% climate change allowance has also been simulated with the 1% AEP event in line with the River Great Ouse approach.

5.3.12 Due to the level of assessment of climate change which informed the Scheme design, the hydraulic modelling approach for the ordinary watercourses should therefore be considered as robust and conservative. This should be considered whilst viewing the hydraulic modelling results contained within this report and the associated provision of mitigation and Scheme assessment.

Surface water (pluvial)

5.3.13 Pluvial modelling has not been undertaken as part of this assessment. A review of the Environment Agency's Flood Map for Surface Water (FMfSW) was undertaken at the outset of this project and it was confirmed that the Scheme crosses several key surface water flow paths. However, these key flow paths are associated with the ordinary watercourses which have been modelled as part of the fluvial assessment (Section 6.3). Based on discussions with the Environment Agency it is considered that this is an appropriate alternative approach to pluvial modelling. This is discussed in more detail within Section 6.4.

Groundwater

5.3.14 A conceptual model aimed at facilitating the groundwater flood risk assessment has been developed in the **Appendix 13.7** - Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**. The model is in line with the technical framework for groundwater risk assessment as defined on the Environment Agency's webpage - Groundwater Risk Assessment for your Environmental Permit (Ref 5-1).

5.3.15 Preliminary qualitative assessment of the Scheme's design in relation to the conceptual model characterised the potential groundwater impact risk areas along the Scheme route into two risk categories: low risk - areas where groundwater is unlikely or only intercepted with an insignificant effect and high risk - areas where groundwater is likely to be intercepted with potentially significant effects (including potential dewatering activities).

5.3.16 The high-risk areas include areas of potential deep excavations/cuttings/borrow pits requiring groundwater dewatering/control activities and areas of potential piling and associated bridge structures.

5.3.17 The model considers the elevation of the deepest point of each cutting against the maximum recorded groundwater level in relation to the existing ground elevation and against the Scheme elevation profile while taking into consideration the geology and hydrogeology beneath the Scheme. Based on the conceptual model, the results of the preliminary assessment showed that most of the cuttings and borrow pits in the high-risk areas are unlikely to impact on the groundwater with a significant effect on the groundwater flood risk during the construction and or operation of the Scheme. A further analytical, quantitative assessment also indicates that the overall impact from or to groundwater in terms of groundwater flood risk during the construction and or operation of the Scheme is minor.

5.3.18 Accordingly, it was not necessary to carry out a detailed, sophisticated numerical groundwater model to further assess the groundwater impact risks, from a groundwater flooding perspective for the overall Scheme at this stage, however; more detailed assessments are recommended during detailed design to confirm any mitigation measures applied for deep cuttings such as at the A1 underpass.

5.3.19 Additionally, it was also noted that given the groundwater condition beneath the Scheme, a numerical model is likely to be unstable, due to the limited thickness (i.e. <1m - 8m) and limited lateral extent of the saturated water-bearing horizon of the superficial deposits (i.e. the River Terrace Deposit and Alluvium) and or due to the poorly saturated/unproductive aquifer with limited groundwater potential of the Oadby Member superficial deposit, which underlies over 80% of the study area.

6 Flood risk baseline

6.1 Overview

6.1.1 This section provides an overview of the baseline flood risk for the identified sources within the study area.

6.2 Fluvial flood risk

Flood Sources

6.2.1 The Environment Agency’s Flood Map for Planning (Ref 6-1) presents a set of flood zones for guidance by developers, councils and communities to explain the probability of fluvial and tidal flooding for Main Rivers. As presented in Figure 6-1, the main flood source within the study area when considering Main Rivers only is the River Great Ouse.

6.2.2 It should be noted that the tributaries of the River Great Ouse which traverse the alignment of the Scheme (**Figure 6.1**) are considered ordinary watercourses, with permissive powers to improve and maintain held by the LLFA and IDB. Unless detailed modelling has been undertaken, flood extents associated with these ordinary watercourses will not be presented on the Environment Agency’s Flood Map for Planning (Ref 6-1).

6.2.3 There are a number of these watercourses (Hen Brook, South Brook, Rectory Farm, Begwary Brook and Wintringham Brook) where flood extents are shown on the Environment Agency’s Flood Map. The Environment Agency confirmed in August 2017 that a series of 2D only TUFLOW models have been produced for these watercourses and therefore flood extents have been generated.

6.2.4 As shown in **Figure 6.1**, most of the Scheme is located within Flood Zone 1 (low probability), except where it traverses each of the watercourses. In these locations the Scheme is shown to coincide with Flood Zone 3 (high probability).

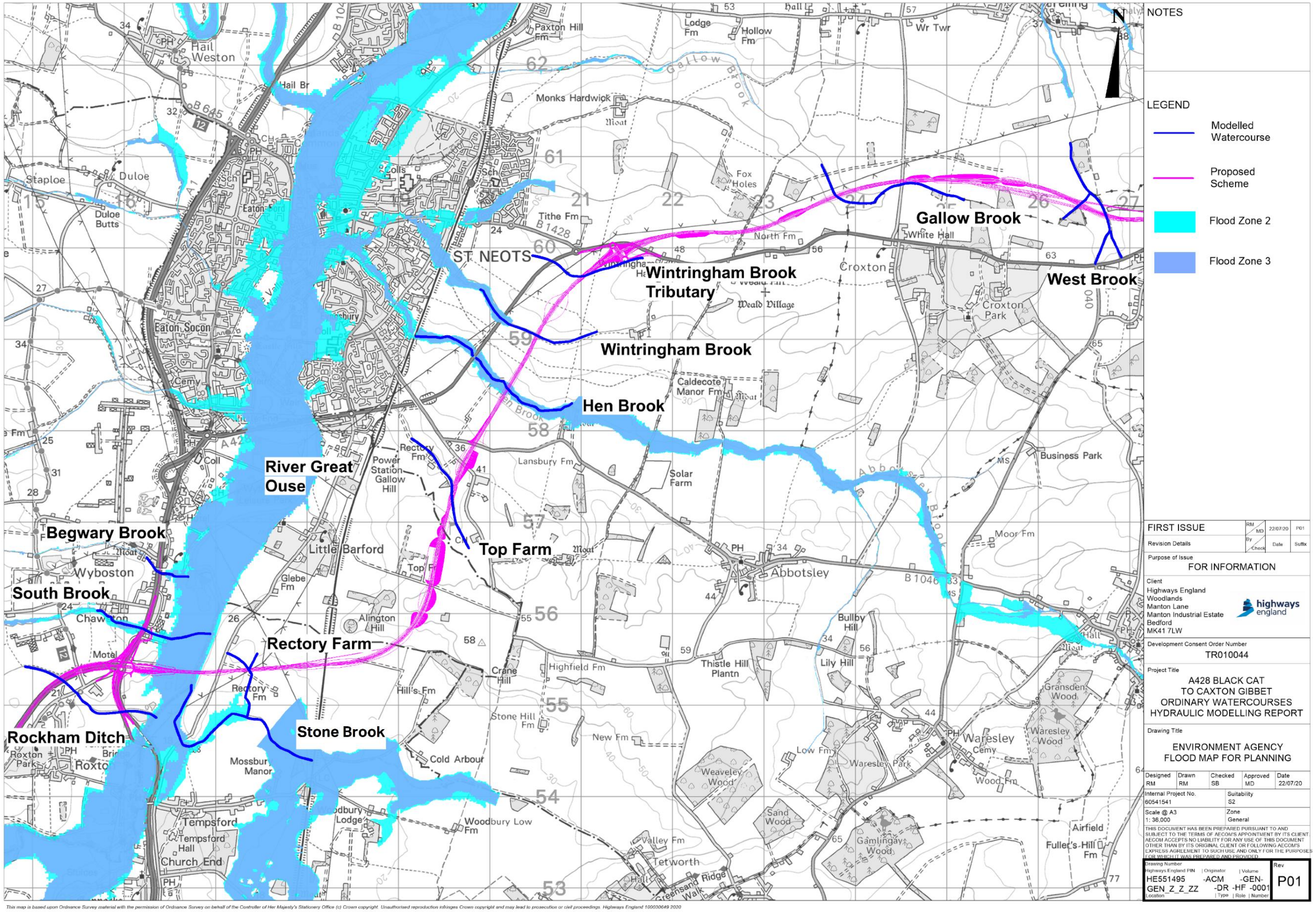

Figure 6.1 Environment Agency's Flood Map for the majority of watercourses crossed by the Scheme

Historical flooding

6.2.5 Records of historical flooding events in the study area have been collected from the Environment Agency, as shown in **Table 6-1.**

Table 6-1 Historical Fluvial Flood Events

Flood Event	Start	End	Source	Cause
March 1947	13/03/1947	17/03/1947	River Great Ouse	Channel Capacity Exceeded (no raised defences)
October 1987	21/10/1987	24/10/1987	Unknown	Channel Capacity Exceeded (no raised defences)
May 1988	08/05/1988	09/05/1988	Unknown	Unknown
Easter 1998	08/04/1998	15/04/1998	River Great Ouse	Channel Capacity Exceeded (no raised defences)
October 2001	21/10/2001	24/10/2001	River Great Ouse	Channel Capacity Exceeded (no raised defences)
January 2003	22/12/2002	04/01/2003	Unknown	Unknown

6.2.6 Environmental Agency's map showing recorded flood outlines is presented in **Figure 6.2**.

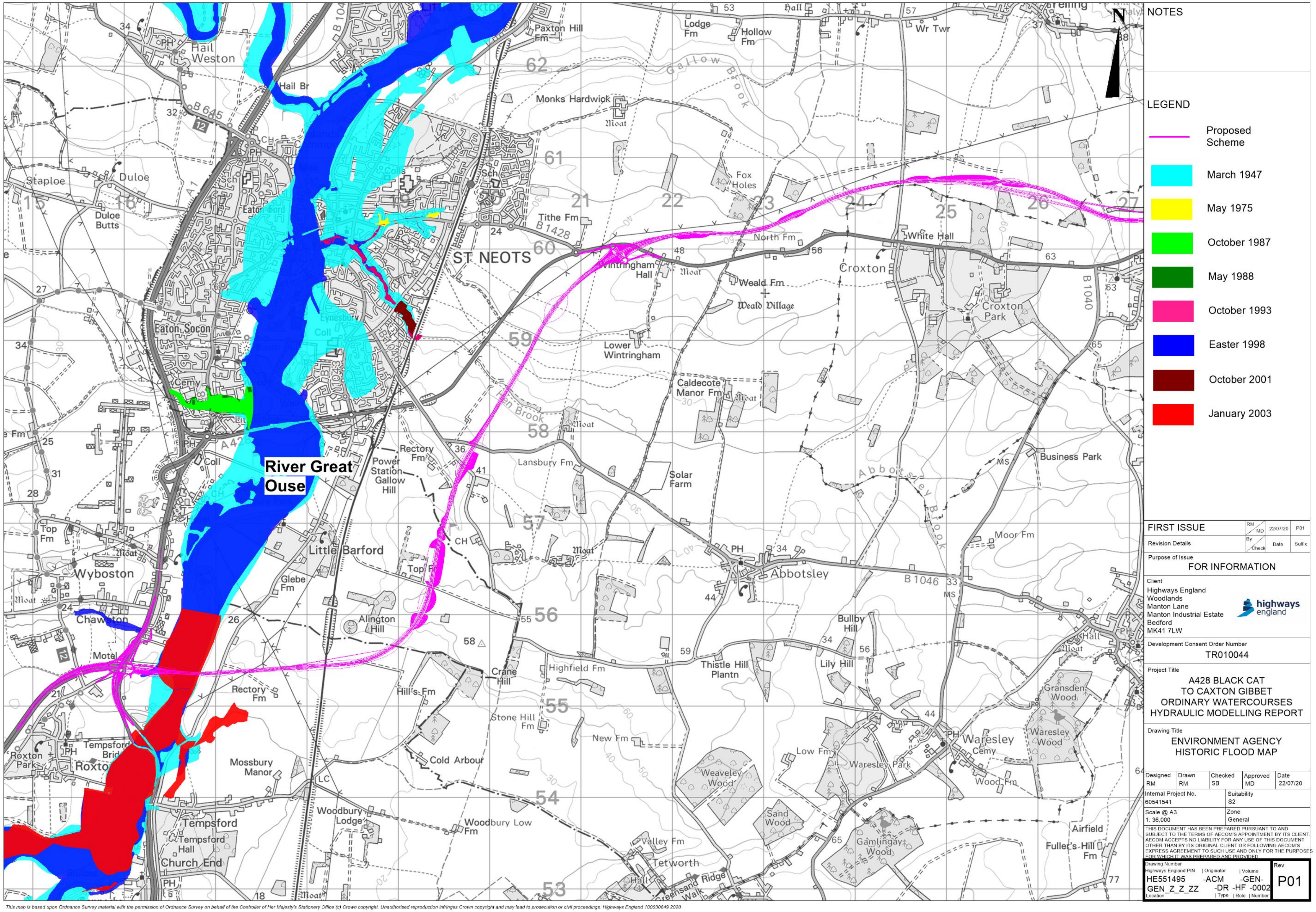

Figure 6.2 Environment Agency Historic Flood Map

6.3 Baseline hydraulic modelling

River Great Ouse

6.3.1 As part of this project, the Environment Agency provided the 2015 lower Ouse 1D-2D FMP-TUFLOW hydraulic model which was originally commissioned to produce strategic scale flood mapping for the River Great Ouse from Great Barford to Stretham.

6.3.2 A key limitation of this model, however, was the coarse representation of the floodplain using a 20m grid which would not provide sufficient resolution to assess the flood risk to and from the Scheme. Furthermore, the topography of the floodplain within the area of interest has changed since the 2015 lower Ouse model was constructed.

6.3.3 Following consultation with the Environment Agency in 2017, 2019 and 2020 in relation to the Scheme, the following approach was agreed in adopting the 2015 lower Ouse model as the 'Baseline' model to assess the risk of flooding to and from the Scheme:

a. The model has been trimmed north of the urban area of St Neots to improve model performance and focus on the area of interest.

b. The hydrological inflows have not been changed from the received model except to reduce the intervening catchment lateral inflows to the revised model limits.

c. An additional 10m resolution grid has been nested into the model at the A428 crossing location to improve representation of the floodplain.

d. The LiDAR DTM has been updated with the latest available data (2017) to more accurately represent the current and proposed floodplain topography.

e. The proposed Caxton Quarry Restoration ground elevations and water levels have been added to improve the expected topography in and around the proposed A428 crossing. It is anticipated that by the time of construction, the quarry restoration will have been completed and therefore it was agreed with the Environment Agency that these should be included within the model.

f. Three additional river cross sections have been surveyed at the proposed A428 crossing location of the River Great Ouse and built into the 1D network. No further changes were made to the 1D channel network representation.

6.3.4 For more detail regarding these model updates, alongside information relating to the hydrological analysis, model representation, boundary conditions, roughness and other improvements, please refer to Section 2 in the River Great Ouse Hydraulic Modelling Report (Annex A). A full suite of results can be viewed within Section 3 of the same document.

6.3.5 The output of the baseline hydraulic modelling for the River Great Ouse for the 1% AEP +35% climate change event is presented in **Figure 6.3**. Floodplain depths are generally observed to be between 1 metre – 2 metres with the largest depths of flooding intuitively being observed within the restored quarry ponds where maximum flood depths are over 3 metres. There is also significant floodplain attenuation upstream of the A1 River Great Ouse crossing where maximum flood depths are consistently between 1 metre – 2 metre during this event.

6.3.6 As agreed with the Environment Agency, the 1% AEP +65% climate change event was also simulated as a sensitivity run with results discussed in detail within the River Great Ouse Hydraulic Modelling Report (Annex A). Flood extents are similar to the 1% AEP +35% climate change event however flood depths naturally increase.

6.3.7 It should be highlighted that a comparison of the baseline modelling flood extents and the corresponding Environment Agency Flood Zones has been undertaken with figures presented within Section 3 in Annex A. To summarise, the modelled 1% AEP and 0.1% AEP flood extents show a good level of agreement to the published Flood Zone 3 and Flood Zone 2 respectively, with slight differences associated with the inclusion of the proposed quarry restoration which do not form as part of the Environment Agency mapping presently. It is anticipated that restoration of the quarry will be complete by the time the Scheme is constructed.

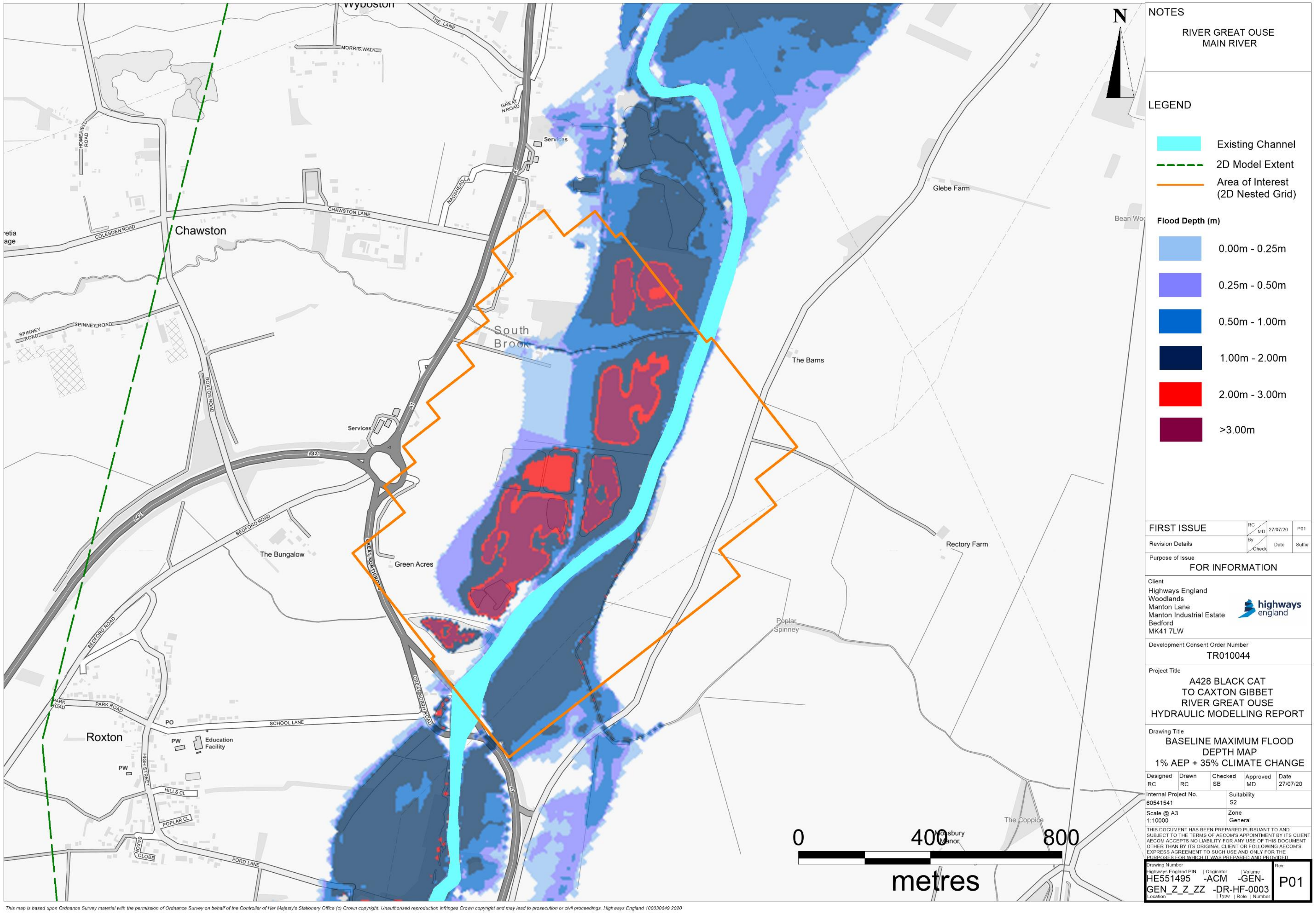

Figure 6.3 Baseline hydraulic modelling results for River Great Ouse (1% AEP + 35% climate change event)

Hen Brook

6.3.8 Hen Brook is a watercourse located to the south-east of St Neots, which flows through agricultural fields to the north of the B1046 near Abbotsley receiving flow from other minor watercourses and land drains.

6.3.9 It was confirmed with the Environment Agency in August 2017 that a 2D model of this watercourse exists, however it was explained that this has previously been rejected due to outdated hydrology and poor channel detail. It was therefore agreed that a new 1D-2D FMP TULOW model was required in the area of the Scheme, representing the ordinary watercourse reach only.

6.3.10 The only structure along the reach that has been modelled for the baseline is the existing culvert beneath the A428. For more information on how this model was created please refer to Section 10 of the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA).

6.3.11 The output of the baseline hydraulic modelling for Hen Brook for the 1% AEP +65% climate change event is presented in **Figure 6.4**. Out of bank flooding is largely contained within the surrounding agricultural fields with flood depths reaching a maximum of approximately 0.75 metre in low lying areas. There are areas where flood depths are greater than this, but these occur within low lying field ditches where deeper flood depths and accumulation of floodplain water is expected.

6.3.12 At the existing A428, the highway presents a barrier to floodplain flow and therefore once out of bank flow occurs, floodwater backs up against the road. Flood depths within the vehicular underpass beneath the existing A428 at this location are approximately 0.64 metre.

6.3.13 It should be noted that other than the existing A428 there are no other sensitive receptors such as residential and commercial property within close proximity to the Hen Brook watercourse with the floodplain largely undeveloped. The cover level of the existing A428 carriageway is elevated more than 3 metres above the surrounding floodplain and results have demonstrated that this highway is not at risk of inundation from the watercourse. Beyond the downstream boundary there is a railway line, however this is raised more than 5 metres above the surrounding floodplain and is therefore not considered to be at risk.

Figure 6.4 Baseline hydraulic modelling results for Hen Brook (1% AEP + 65% climate change event)

Rectory Farm

6.3.14 Rectory Farm originates as two tributaries (Barford and Spinney branches) located in agricultural fields south of Little Barford. These tributaries confluence at a farm access track where the watercourse flows through a small culvert. Rectory Farm continues to flow in a southerly direction until it confluences with the Stone Brook.

6.3.15 There was no available model of this watercourse and therefore a new 1D-2D FMP TULOW model was developed in the area of the Scheme. For more information on how this model was created please refer to Section 11 of the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA).

6.3.16 The output of the baseline hydraulic modelling for Rectory Farm for the 1% AEP +65% climate change event is presented in **Figure 6.5**. Out of bank flooding is largely contained upstream of the farm access track crossing with a maximum depth of approximately 0.68 metre in the low-lying area. Flow is constricted by the culvert and therefore water backs up on the floodplain. This is exacerbated by the raised farm track road which presents a barrier to flow.

6.3.17 Floodwater overtops the farm track road where levels are naturally lower, propagating downstream. Generally, flood depths downstream of the farm track road reach up to 0.20 metre.

Figure 6.5 Baseline hydraulic modelling results for Rectory Farm (1% AEP + 65% climate change event)

South Brook

6.3.18 South Brook is a watercourse located to the south of St Neots, which flows through agricultural fields in Chawston. The watercourse flows east beneath the existing A1 Great North Road before reaching its outfall to the River Great Ouse.

6.3.19 It was confirmed with the Environment Agency in August 2017 that a 2D model of this watercourse exists, however it was explained that this has previously been rejected due to outdated hydrology and poor channel detail. It was therefore agreed that a new 1D-2D FMP TULOW model was required in the area of the Scheme. For more information on how this model was created please refer to Section 12 of the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA).

6.3.20 The output of the baseline hydraulic modelling for South Brook for the 1% AEP +65% climate change event is presented in **Figure 6.6**. Results show that out of bank flooding occurs on the floodplain to the north and south of South Brook upstream of the A1 Great North Road. Maximum depths typically reach up to 0.75 metre in this event. The A1 Great North Road acts as a barrier to flow, with floodwater pooling on the floodplain upstream of the road embankment. Some floodwater overtops the road on the southern side, with depths up to 0.15 metre. There is no property flooding present as properties are located approximately 40 metre from the maximum modelled flood extent and 0.40 metre above the maximum flood level.

6.3.21 Out of bank flooding is also present downstream of the A1 Great North Road where floodwater depths typically reach up to 0.10 metre. There is a small area of floodwater adjacent to the channel where depths reach up to 0.50 metre where the land elevation is lower than the surrounding floodplain. The model demonstrates that floodwater flows out of bank and spreads across the floodplain on both the north and south side of the watercourse as the area is generally flat.

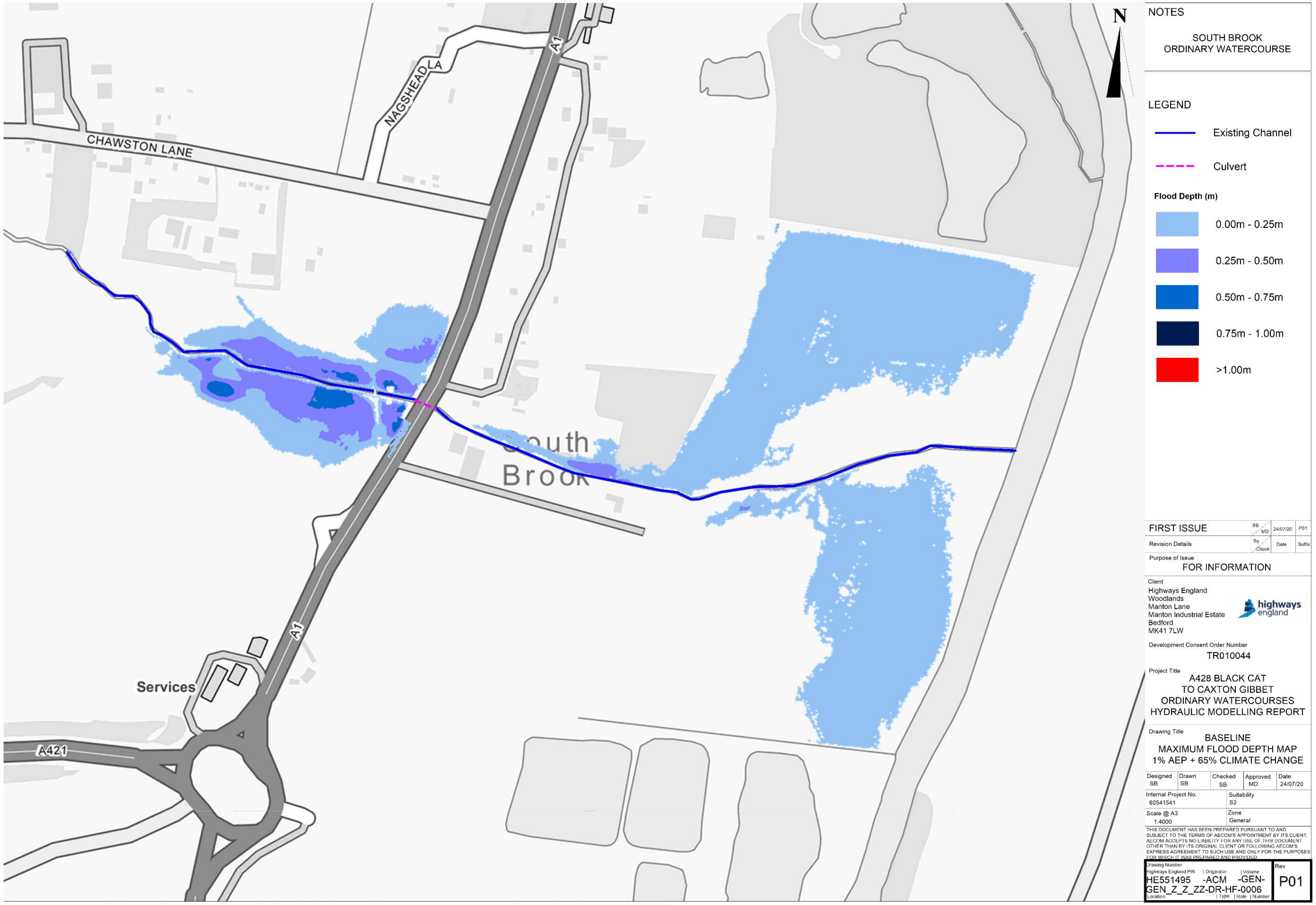

Figure 6.6 Baseline hydraulic modelling results for South Brook (1% AEP + 65% climate change event)

Other Ordinary Watercourses

6.3.22 The remaining ordinary watercourses, modelled using a 1D FMP only approach, include:

a. West Brook

b. Wintringham Brook

c. Wintringham Brook Tributary

d. Gallow Brook

e. Begwary Brook

f. Rockham Ditch

g. Top Farm

6.3.23 As discussed in Section 5.4 of this report, flood extents are not generally an output of 1D only models however they produce data such as levels, flows, flow volumes and velocities which are useful metrics in comparing baseline and proposed scenarios.

6.3.24 These 1D only models are therefore best assessed through comparison to the proposed scenario. As such, Section 7 of this report, provides details regarding this comparison, and how the Scheme affects results. For more information about the model setup and discussion of results for these ordinary watercourses please refer to Sections 3 – 9 in the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA).

6.4 Surface water flood risk

6.4.1 It can be identified from the Environment Agency's FMfSW (**Figure 6.7**) that areas at risk from surface water flooding are present within the study area.

6.4.2 The majority of the surface water flood risk in the study area is categorised as 'Very low' (less than 0.1% AEP). However, where the Scheme traverses an ordinary watercourse, the surface water flood risk increases and becomes 'Low' (between 0.1% and 1% AEP), 'Medium' (between 1% and 3.33% AEP) and 'High' (greater than 3.33% AEP). Naturally, risk is higher in areas closest to the ordinary watercourse, as shown in **Figure 6.7**.

6.4.3 With these surface water flow paths associated with ordinary watercourses, pluvial modelling has not been undertaken as these have already been considered as part of the fluvial assessment. Following consultation with the Environment Agency, this is considered as an appropriate alternative method to understanding the impact of these flow paths in relation to the Scheme.

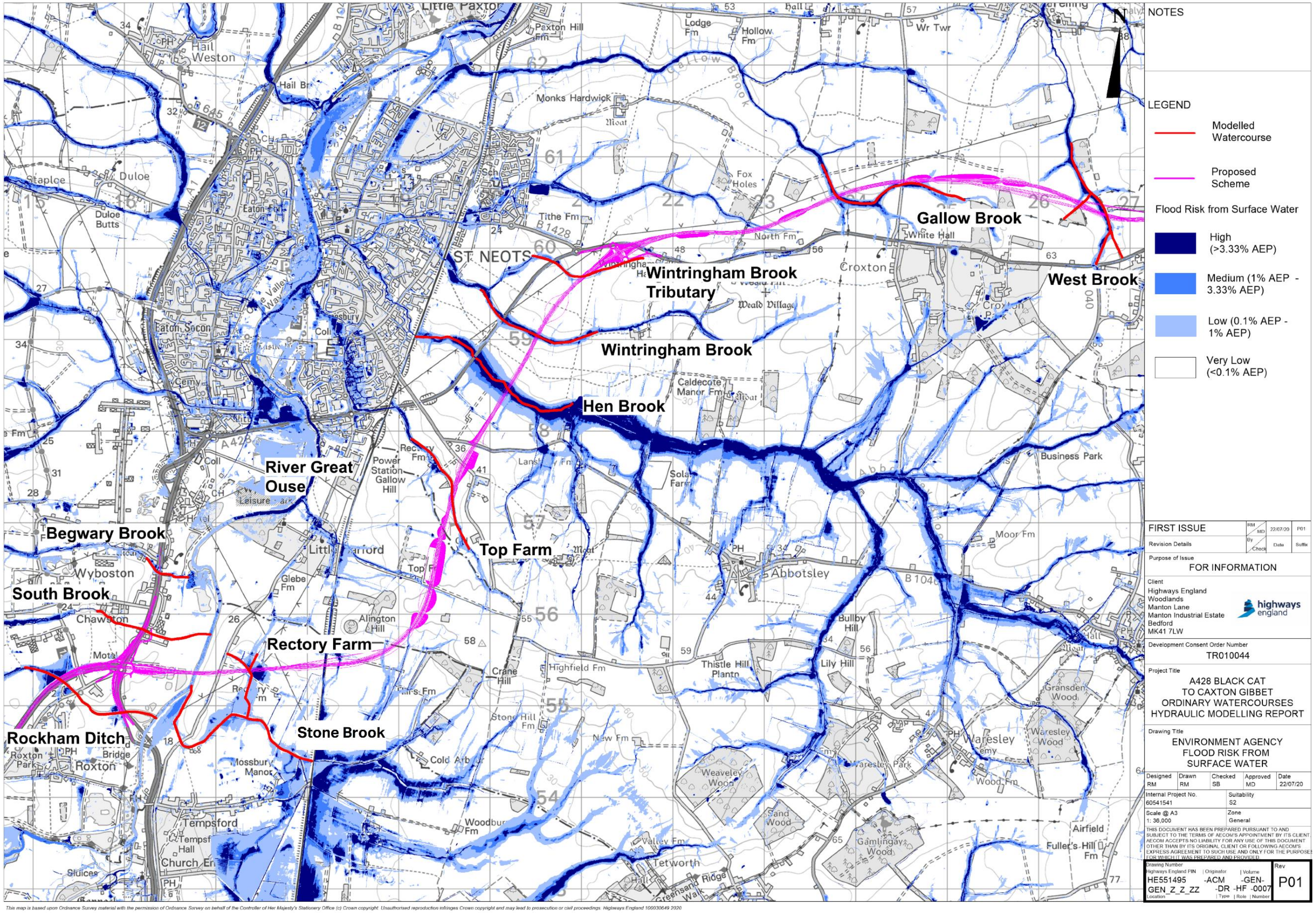

Figure 6.7 Environment Agency's Flood Map from Surface Water

6.4.4 Highways England’s Drainage Data Management System (DDMS) (Ref 6-2) data on the existing A428 contains reference to 38 surface water flooding events between Black Cat roundabout and Caxton Gibbet roundabout. These occurred between 2010 and 2019 with a severity 0-4 out of 10 for most of the events, while six events rated between 5-6. The severity is rated by Highways England using the following factors: impact on traffic, duration of impact, road classification and annual average daily traffic for one carriageway. Defective gullies are the main source of flooding, while excessive rainfall combined with snowmelt is the cause of a minority of recorded flood events.

6.5 Groundwater flood risk

6.5.1 The Areas Susceptible to Groundwater Flooding (AStGWF) map, mentioned in planning policies (see Section 4.3) such as the Huntingdonshire District Council SFRA (Ref 4-7), shows the study area is susceptible to groundwater flooding from superficial deposits. The area around the existing Black Cat roundabout and the section from Cambridge Road roundabout to Caxton Gibbet roundabout is indicated with a 75% (i.e. >75%) susceptibility from superficial deposits flooding. The area between the existing Black Cat and Cambridge roundabouts is indicated predominantly with under 25% (<25%) susceptibility from superficial deposits flooding. However, this published map was produced from a regional-scale model, showing groundwater flood areas on a 1 kilometre square grid, and therefore may vary from actual site-specific groundwater conditions. The AStGWF data should be used only in combination with other information, for example local data or historical data.

6.5.2 A conceptual hydrogeological model has been developed in the Appendix 13.7 - Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**, to define the baseline groundwater flood risk. The model is based on the geological and hydrogeological conditions of the Scheme area, described in Section 2 of this report.

6.5.3 Borehole record from historical data (1989 to 2015) and the 2019/2020 geotechnical ground investigation data have been incorporated in the development of the baseline conceptual model.

6.5.4 Based on the ground investigation data, the conceptual model assessment (see Section 5.3.14) and the groundwater susceptibility flood risk map, the risk of groundwater flooding is considered to be low in the vast majority of the study area with the only exception being the western part of the Scheme where the potential for groundwater flooding risk is considered to be high due to the shallow groundwater conditions and the potential for groundwater-surface water interaction in the floodplain of the River Great Ouse.

6.6 Sewer flood risk

6.6.1 The Anglian Water records mentioned in the SFRA for Bedford Borough Council (see section 4.3) show that the locations with greatest numbers of flooding records are localised in the centre of the borough, outside of the study area of this FRA.

6.6.2 As mentioned in Section 4.3.11 of this report, the Cambridge and South Cambridgeshire Level 1 SFRA, indicates some localised sewer and pluvial flood events in Croxton and Eltisley, within the study area of this FRA.

6.6.3 However, given the rural nature of the area surrounding the Scheme and known records of previous incidents, the flood risk from sewers is considered to be low.

6.7 Artificial sources of flood risk

6.7.1 The risk of flooding from reservoirs due to dam failure is very low throughout the UK. Based on data received from Environment Agency, the following registered large raised reservoirs (i.e. capacity of 25,000 cubic metres or more of water above ground level) could present a flood risk to part of the study area in the unlikely event of a dam failure:

Table 6-2 Registered reservoirs sources of flood risk

Reservoir	Location (National Grid Reference)	Distance from the Scheme (km)
Grafham Water	TL 17000 67000	12
Tythe Farm Reservoir (previously registered as Tithe Farm Reservoir)	TL 14400 57700	2.5
Southill Park Lake	TL 14500 43000	12
Lower East End Farm	TL 11382 55523	4.5
Great Barford Flood Alleviation- West	TL 11600 52600	5

6.7.2 An extract of the published flood risk map from reservoirs obtained from the Environment Agency website is included in **Figure 6.8**.

6.7.3 The flood risk map indicates that, for the majority of the reservoirs in the vicinity of the Scheme, floodwater would follow the route of the River Great Ouse in case of a dam failure, northwards towards St. Neots. The Environment Agency flood speed and flood depth maps in relation to flood risk from reservoirs have been reviewed for the area in proximity to the existing Black Cat roundabout. The flood speed is predominantly below 0.5 m/s, while flood depths are between 0.3 metre and 2 metres, indicating a low risk.

6.7.4 The largest reservoir in the vicinity of the study area is the Grafham Water reservoir, situated approximately 12 kilometres downstream from the River Great Ouse viaduct. The flood depths generated by this reservoir would be over 2m with a speed of over 2m/s. Although the consequences of flooding from the failure of the Grafham Water dam are potentially high to surrounding communities, the Environment Agency map showing flood depth and speed suggests the high-risk effects from this reservoir, are contained within St. Neots, therefore not affecting the study area of this FRA. The overall risk is therefore considered to be low, also taking into account the inspection regime for the reservoir. The effect of inundation from Grafham Water reservoirs is also discussed in section 6.8.2 of the Huntingdonshire SFRA (Ref 4-7).

6.7.5 Based on this information, the risk of flooding from artificial sources within the study area is considered to be low and is therefore not considered further within this assessment.

6.8 Snowmelt

6.8.1 A review of the Met Office ‘Days of Snow Lying’ (Ref 6-3) annual average for the period 1961 to 1990 against the period 1981 to 2010 indicates that there is a decrease in snow lying days. The Scheme area receives five to ten days per year on average and this is likely to decrease with climate change.

6.8.2 Snowmelt was one of the main factors that led to the catastrophic river floods that began in mid-March 1947 throughout the United Kingdom. The combination of snowmelt, frozen ground and rainfall, caused the flooding of the River Great Ouse over the course of the event. Several proprieties were reported to be flooded in Bedford and surrounding rural areas of low population.

6.8.3 As mentioned in Section 6.4.4, snowmelt in conjunction with heavy rainfall is the cause of a minority of the recorded flood events along the existing A428 as shown on the Highways England’s Drainage Data Management System (DDMS) (Ref 6-2).

6.8.4 The historical risk of flooding from this source, having considered the atmospheric trends, is considered to be low and is not assessed further in this report.

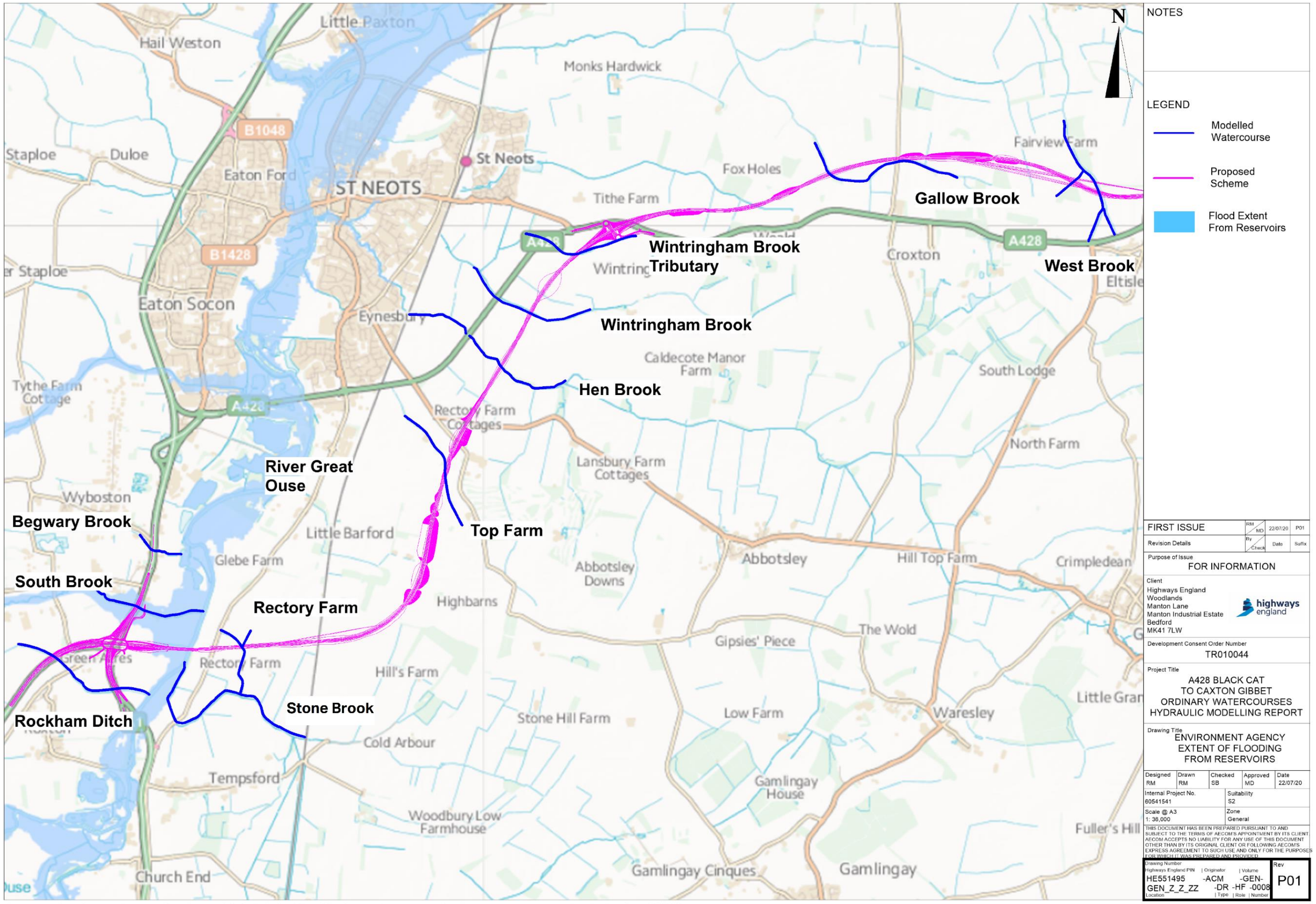

Figure 6.8 Environment Agency's Flood Map from Reservoir (Source: Environment Agency website, 2020)

7 Flood risk to the Scheme – operational stage

7.1 Overview

7.1.1 This section addresses the risk of flooding *to* the Scheme from the identified sources within the study area.

7.1.2 The risk of flooding *from* the Scheme, once fully operational, to other receptors is discussed in Section 8 while the impact of the construction phase is assessed in Section 9.

7.2 Fluvial flood risk

River Great Ouse

7.2.1 The features associated with the Scheme (when fully operational) include piers of the River Great Ouse viaduct located within the 1% AEP flood extent along with sections of the new dual carriageway embankment.

7.2.2 Hydraulic modelling has been undertaken to assess the potential flood risk impacts to these features. Reference to the baseline and proposed modelling demonstrates that the Scheme would be affected by fluvial flooding from the River Great Ouse. However, no detrimental impact is observed from the fluvial hydraulic modelling results and the new dual carriageway would be suitably raised above the flood level of the design event and is therefore not considered to be at risk during the 1% AEP plus 35% climate change scenario.

7.2.3 As discussed in Section 4.2 of this report, the Exception Test is only required for elements of proposed development (Essential Infrastructure) in Flood Zone 3. The appraisal of the Scheme has shown that elements positioned within Flood Zone 3 include the River Great Ouse viaduct piers, sections of the new dual carriageway embankment and floodplain compensation areas to the west of the River Great Ouse. The Scheme satisfies the Exception Test requirement for the Scheme to be safe from flood risk for the lifetime of the development for the River Great Ouse, as discussed in Section 4.2.

Proposed Mitigation

7.2.4 The pier foundations are designed to resist fluvial flood flows interacting with the piers while the new dual carriageway embankment will be raised and designed to resist encroachment from floodwater.

7.2.5 The River Great Ouse floodplain compensation area is designed to compensate for the displacement of the floodplain as a result of the raised embankment. Modelling results have shown that by including the compensation area, flood risk to the Scheme and sensitive receptors is not increased.

7.2.6 With design mitigation, the risk from fluvial flooding from the River Great Ouse is considered to be low.

Ordinary watercourses

7.2.7 The features associated with the Scheme (when fully operational) for the ordinary watercourses, which are located within the 1% AEP flood extent, include the new dual carriageway culverts, the access track culverts and the raised new dual carriageway embankment.

7.2.8 The modelling results show that although fluvial flooding from the ordinary watercourses would affect the Scheme, no significant detrimental effect would result, with the new dual carriageway level suitably above the design flood level. The pond access tracks are raised above the flood level where possible, however; results have shown that during the 1% AEP +65% climate change event parts of the tracks are inundated. The access tracks are not frequently used (being required for maintenance and access to attenuation ponds, also known as attenuation basins) and will therefore be avoided when a flood event of this magnitude occurs.

7.2.9 Within Annex B of this FRA of this report, it is demonstrated through detailed modelling and the inclusion of appropriate mitigation, that there is no detrimental impact on flooding, to ensure compliance with the Exception Test requirement for the Scheme to be safe from flood risk for the lifetime of the development, as discussed in Section 4.2.

Proposed Mitigation

7.2.10 Adjustments to the land profile to facilitate the creation of the embankments and cuttings has the potential to change the catchment characteristics such as altering overland fluvial and surface water flow paths which could increase flood risk from these sources. Embankments have been designed and located to avoid the river channel and provide minimal obstruction of floodplain flows and, where required, appropriate embankment scour protection is to be applied. Modelling has shown that through appropriate culvert design and the provision of compensatory floodplain areas, flood risk to the Scheme has not increased.

7.2.11 The new dual carriageway embankment will also be raised and designed to resist encroachment to fluvial flows.

7.2.12 With appropriate mitigation, the risk from fluvial flooding from the ordinary watercourses is considered to be low.

7.3 Surface water flood risk

7.3.1 As mentioned in Section 7.2, the inclusion of embankments and a raised new dual carriageway has the potential to alter surface water flowpaths associated with ordinary watercourses which could potentially impact flood risk. The impact of this has been addressed through detailed hydraulic modelling with appropriate mitigation included within the Scheme design.

7.3.2 The Black Cat and Caxton Gibbet junction upgrades will comprise of new slip roads and improvements to roundabouts which have the potential to impact surface water flooding by increasing impermeable area and impact flow paths.

Proposed Mitigation

7.3.3 The new dual carriageway is designed to minimise the risk of flooding by incorporating current design standards and future climate change allowance to improve its resilience through the use of sustainable drainage techniques.

7.3.4 The Scheme comprises twelve main drainage catchments, generally based on the geometry of the road alignment. Each of these catchments has been divided into sub catchments in order to undertake preliminary road drainage design. From the ground investigation surveys it was discovered that the groundwater level is close to the surface and therefore infiltration techniques to manage surface water are unsuitable. It is therefore proposed to discharge surface water from the Scheme to local watercourses. In some areas, this is via attenuation ponds. For more information on the features used to sustainably manage and discharge surface water away from the Scheme, ensuring the highway remains safe throughout its lifetime, please refer to **Appendix 13.3** (Road Drainage Strategy Report) of the Environmental Statement Appendices **[TR010044/APP/6.3]**.

7.3.5 With design mitigation, the risk to the Scheme from surface water flooding is considered to be low.

7.4 Groundwater flood risk

7.4.1 As described in the **Appendix 13.7** Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**, the potential impacts on the Scheme are related mainly to the elements of the Scheme (such as cuttings and borrow pits) with potential deep excavation activities and structures that will potentially intercept the groundwater table (i.e. high-risk area) and could lead to increased groundwater flooding risk on the Scheme.

7.4.2 The Scheme will incorporate measures such as groundwater flow path barriers at the A1 cutting, as detailed within of the Environment Statement (refer to the Operation section of Chapter 13, Road drainage and the water environment of the Environmental Statement [TR010044/APP/6.1]), to minimise groundwater ingress into the drainage system and road pavement, once the Scheme is fully operational. Additionally, the drainage design incorporates allowances for minimal ingress of groundwater associated with natural groundwater flows and volumes. With the proposed design mitigation, the risk of flooding from groundwater to the A1 underpass, once the Scheme is fully operational, is considered to be low.

7.5 Sewer flood risk

7.5.1 Given the rural nature of the study area and known records of previous incidents, the flood risk from sewers and drains to the Scheme, once fully operational, is considered to be low. The risk of flooding is minimised by incorporating design standards and future climate change allowances. Attenuation features have been designed to detain runoff from all events expected to occur with 1% annual probability or more frequently which will reduce the risk of flooding when the drainage network is unable to discharge due to high water levels. Further details on the drainage strategy for the Scheme are included in **Appendix 13.3** of the Environmental Statement Appendices **[TR010044/APP/6.3].**

8 Flood risk from the Scheme – operational stage

8.1 Overview

8.1.1 This section provides an overview of the risk of flooding *from* the Scheme, once fully operational, to other receptors. The flood risk *from* the construction works is addressed in Section 9.

8.2 Fluvial flood risk

River Great Ouse

8.2.1 To determine the potential change in flood risk from the Scheme, once operational (as described in Section 3), hydraulic modelling has been undertaken for the River Great Ouse. Details of how the Scheme elements have been represented, alongside a full suite of results are included in the River Great Ouse Hydraulic Modelling Report (Annex A below). To summarise:

a. The proposed viaduct across the River Great Ouse has been represented within the 1D FMP model as a bridge unit.

b. Four bridge piers have been specified across the floodplain using flow constriction units.

c. Topographic amendments have been applied in the 2D model to represent the new dual carriageway embankment.

d. The floodplain compensation area has been represented using topographic amendments to the floodplain, to compensate for the floodplain storage volume lost as a result of the proposed embankment. The floodplain compensation volumes include top banks of the existing quarry ponds. The top banks of the ponds and sections of the western riverbank would be lowered (see Section 2.13 of the River Great Ouse Hydraulic Modelling Report – Annex A), where required, to provide hydraulic connectivity between the compensation area and the watercourse.

8.2.2 Outputs from the proposed modelling scenarios have shown that when results for the 1% AEP +35% climate change are compared with the baseline scenario (Figure 8-1), flood depths and extents are broadly similar. Maximum flood depths within the area of interest are approximately 1 – 2m and, as intended, flood extents are increased to the south-west of the proposed crossing within the proposed floodplain compensation storage area.

8.2.3 It is noted that the maximum flood depths are shown to be lower around the two restored quarry ponds within the proposed scenario when compared to the baseline. This is because the water level of the floodplain compensation storage area has been represented using a topographic surface and not initial water level polygons which have been applied in the baseline scenario. Saliently, in both scenarios the existing ponds are considered full at the outset of the simulation and the actual base level of the restored quarry ponds will not change in the proposed scenario, therefore not affecting the modelled floodplain compensation storage volumes or area requirements in the proposed design.

8.2.4 **Figure 8.2** shows a maximum water level difference plot, which provides a direct comparison of the Scheme and baseline scenario and therefore shows the increases and decreases in water elevation that are attributable to the Scheme elements. It is important to note that this figure does not show the entire flood extent but instead shows areas of water level change.

8.2.5 The results presented in **Figure 8.2** indicate that during the 1% AEP + 35% climate change event there are localised changes in maximum water elevation attributable to the Scheme around the River Great Ouse viaduct and within the proposed compensation storage area. Importantly, there is a general reduction in maximum water elevations of less than 10mm outside of the Order Limits, upstream of the River Great Ouse viaduct which indicates a net flood risk benefit. This is further demonstrated by the area outside of the Order Limits to the south of the Scheme which was wet in the baseline scenario and is shown to be dry during operation of the Scheme.

8.2.6 **Figure 8.2** also shows that there is an increase in maximum water elevation within the proposed floodplain compensation storage area as intended within the design. Maximum floodplain water elevations increase by +50mm to +100mm when compared to the baseline scenario and inundate both ponds. Intuitively, flooding is removed where the A428 embankment crosses the floodplain and flooding is increased where the restored quarry has been excavated to create the floodplain compensation storage area.

8.2.7 There is an increase in maximum flood depths of +10mm to +50mm, within a relatively small localised area on the right bank of the River Great Ouse, upstream of the viaduct, immediately outside of the Order Limits . This is within heavily vegetated sloped agricultural fields within the floodplain that already floods to a depth of over 1 metre during the 1% AEP + 35% climate change event baseline scenario. It is considered that these increases can easily be eliminated in the detailed design phase by very minor adjustments in the design parameters such as viaduct or flood compensation earthwork slopes and minor modelling parameters to optimise overall hydraulic results and will remain within the Order Limits..

8.2.8 To understand the upstream and downstream impacts of the Scheme, the maximum 1D channel stage results for the baseline and proposed scenarios have been compared. Full details of this comparison are in Section 3.3 in Annex A. To summarise, results have shown that for all design events there is a reduction in the channel maximum water level upstream of the Scheme between -10mm to -60mm and no change in the maximum water level downstream. This is attributed to the operation of the proposed compensation storage area. Similar results are experienced when flow hydrographs are compared between the baseline and proposed scenarios.

8.2.9 As agreed with the Environment Agency, the 1% AEP +65% climate change event was also simulated as a sensitivity run. Similar to the 1% AEP +35% climate change event, the flood extents associated with the proposed scenario are broadly similar to the baseline. As intended, there is an increase in flood depth and extent within the proposed flood compensatory storage area. Upstream of the River Great Ouse viaduct there is a general reduction in max water elevations (outside of the Order Limits) and downstream the water level change is very small, indicating a net flood risk benefit.

8.2.10 In conclusion, with informed flood mitigation being provided as part of the Scheme, results have shown that flood risk benefits are experienced upstream of the Scheme crossing, while downstream water levels and flows are maintained as existing. Consequently, there is no increase in fluvial flood risk to sensitive receptors i.e. properties.

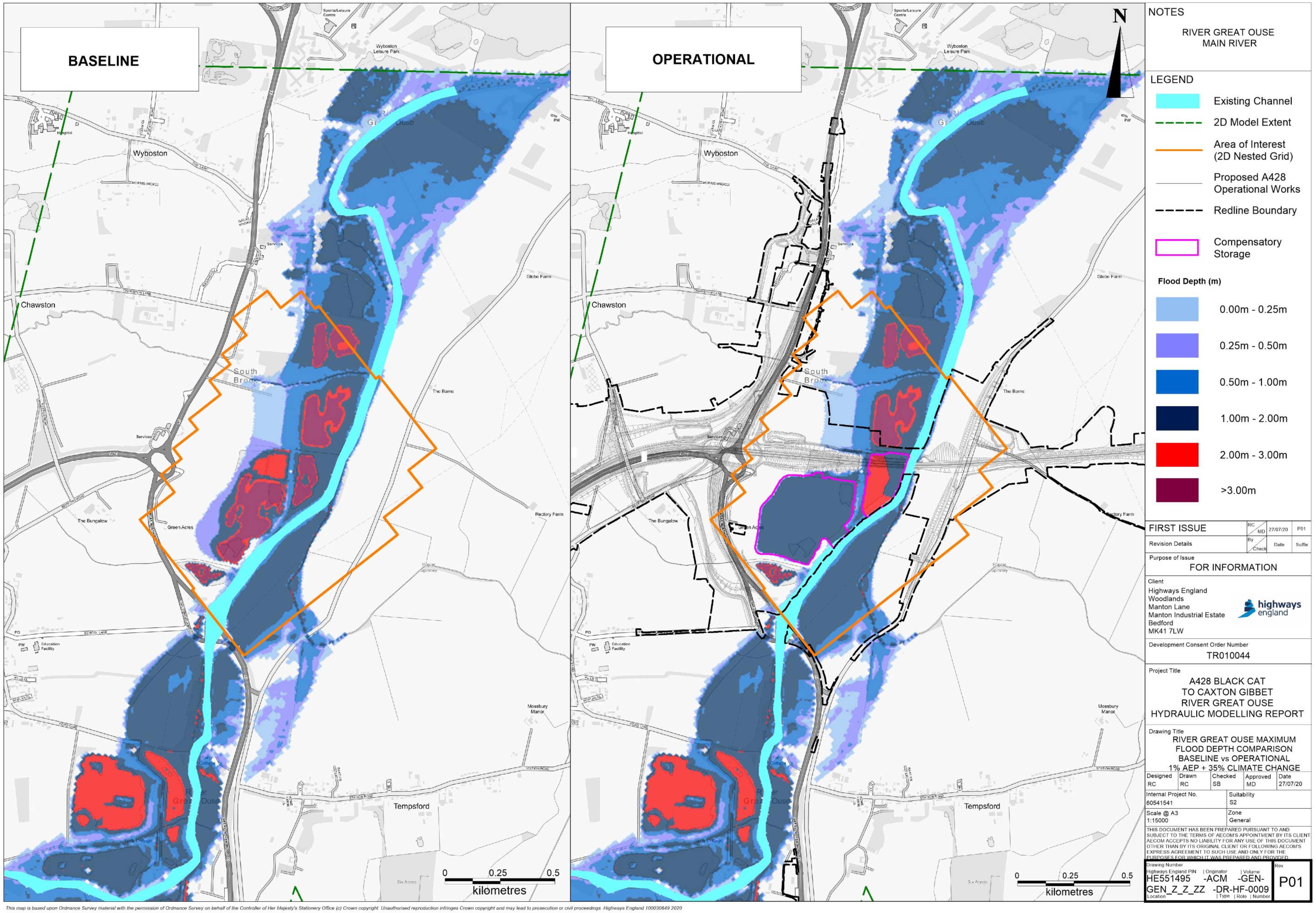

Figure 8.1 Modelled River Great Ouse 1% AEP + Climate Change (+35%) Maximum Flood Depth Comparison, Baseline vs Operational

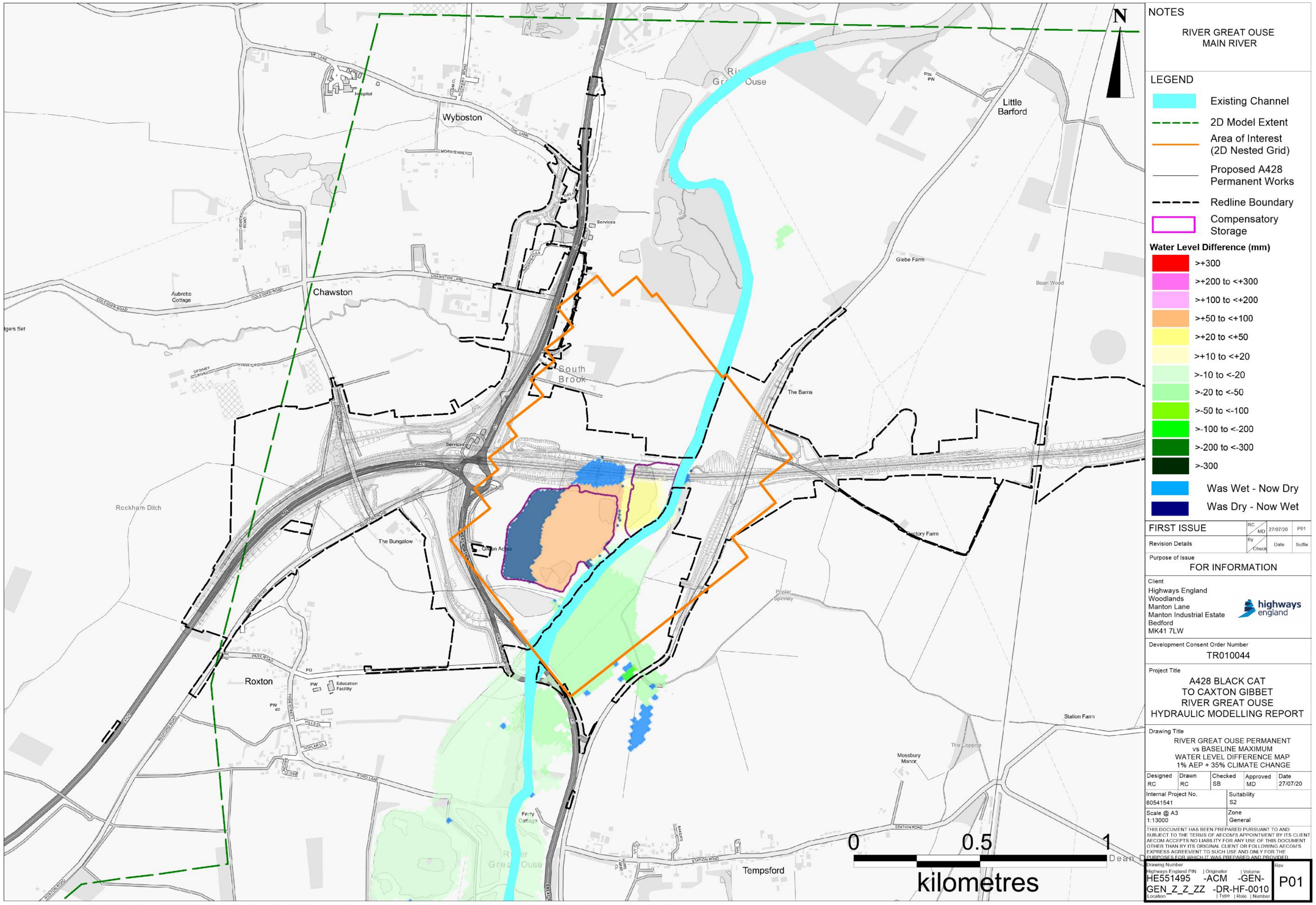

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Figure 8.2 Modelled River Great Ouse 1% AEP + Climate Change (+35%) Maximum Water Level Difference, Operational vs Baseline

Hen Brook

8.2.11 To determine the potential change in flood risk from the Scheme, once operational (as described in Section 3), hydraulic modelling has been undertaken at Hen Brook. Details of how the Scheme elements have been represented are included in Section 10 of the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA). To summarise:

a. The 1D FMP model was updated to reflect the realigned channel in the location of the Scheme.

b. Two new culverts were introduced to the 1D FMP model at the location of the Scheme (Hen Brook culvert) and also at the location of a proposed pond access track. Additionally, six high flow culverts were introduced to maintain conveyance of Hen Brook through the new dual carriageway embankment.

c. Topographic amendments were applied to the 2D model to represent the proposed new dual carriageway embankment and access track.

d. An online floodplain compensation area was represented using topographic amendments to the DTM, to compensate for the floodplain storage volume lost as a result of the proposed embankment.

8.2.12 Outputs from the proposed modelling scenarios have shown that the maximum flood depths and extents for the 1% AEP +65% climate change are broadly similar to the baseline scenario. The only area of difference is around the Scheme where the flood extent has been removed (in the location of the new dual carriageway embankment) and consequently this leads to increases in flood depth and extent upstream, mainly within the designated floodplain compensation area.

8.2.13 **Figure 8.3** shows a maximum depth difference plot, which provides a direct comparison of the baseline and proposed scenarios. As expected, there is a significant increase in water level within the floodplain compensation area and a decrease at the location of the new dual carriageway embankment.

8.2.14 Within the wider floodplain there are generally decreases in flood depth (up to -600mm) immediately upstream and downstream of the Scheme which is attributable to the designated area of floodplain compensation.

8.2.15 There are other areas shown in ‘pink’ and ‘red’ where flood levels increase however these coincide with the proposed realignment of the new channel (i.e. where no flood extent is shown in the 2D floodplain in the baseline) therefore naturally this area will be shown to have increases in flood depth.

8.2.16 There is a small increase in flood depth (up to +10mm) immediately upstream of the proposed A428 highway adjacent to the left bank, however this is in an undeveloped agricultural area and therefore does not impact on any sensitive receptors. This is also located within the Scheme Order Limits and permanent land acquisition area.

8.2.17 Comparison of 1D and 2D flows also indicate that there is no increase in peak flows in areas downstream of the Scheme. With the compensatory storage area in place, there is no detriment on peak flows. This is discussed in more detail within Section 10 of Annex B of this FRA.

8.2.18 Overall, the modelling results have shown that with mitigation in place through floodplain compensation, the Scheme does not have a negative impact on channel flow downstream or flood depths and levels on the floodplain outside of the Scheme Order Limits.

Figure 8.3 Modelled Hen Brook 1% AEP + Climate Change (+65%) Maximum Depth Difference, Baseline vs Operational

Rectory Farm

8.2.19 To determine the potential change in flood risk from the Scheme, once operational (as described in Section 3), hydraulic modelling has been undertaken at Rectory Farm. Details of how the Scheme elements have been represented are included in the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA). To summarise:

a. The 1D FMP model was updated to reflect the realigned channel in the location of the Scheme.

b. Two new culverts were introduced to the 1D FMP model at the location of the Scheme and also at the location of a proposed pond access track. These are located within the realigned channel.

c. Topographic amendments were applied to the 2D model to represent the proposed new dual carriageway embankment and access track.

d. Floodplain compensation areas were represented using topographic amendments to the DTM to compensate for the floodplain storage volume lost as a result of the Scheme. An offtake channel was also modelled in the 2D domain to allow water to utilise the largest compensation area to the north-east during high AEP events.

8.2.20 Outputs from the proposed modelling scenarios have shown that the maximum flood depths and extents for the 1% AEP +65% climate change are broadly similar to the baseline scenario. Flooding has increased within the compensation areas (as expected) and consequently there is a slight reduction in the flood extents upstream of the Scheme.

8.2.21 **Figure 8.4** shows a maximum depth difference plot, which provides a direct comparison of the baseline and proposed scenarios. As expected, there is a significant increase in water level within the floodplain compensation area and a decrease at the location of the new dual carriageway embankment.

8.2.22 There are a few isolated areas where model results show increases in flood depth up to +36mm, however; these are located in undeveloped agricultural areas. It should be noted that these are all located within the Order Limits and are in areas which already flood during the baseline scenario. There are increases in flood depth of up to 60mm along a ~8 metre section of the proposed field access route to the north of the A428 carriageway, however; this is unlikely to impact upon the access track use, given the area is already flooding in the baseline scenario and the magnitude of this change is under 60mm.

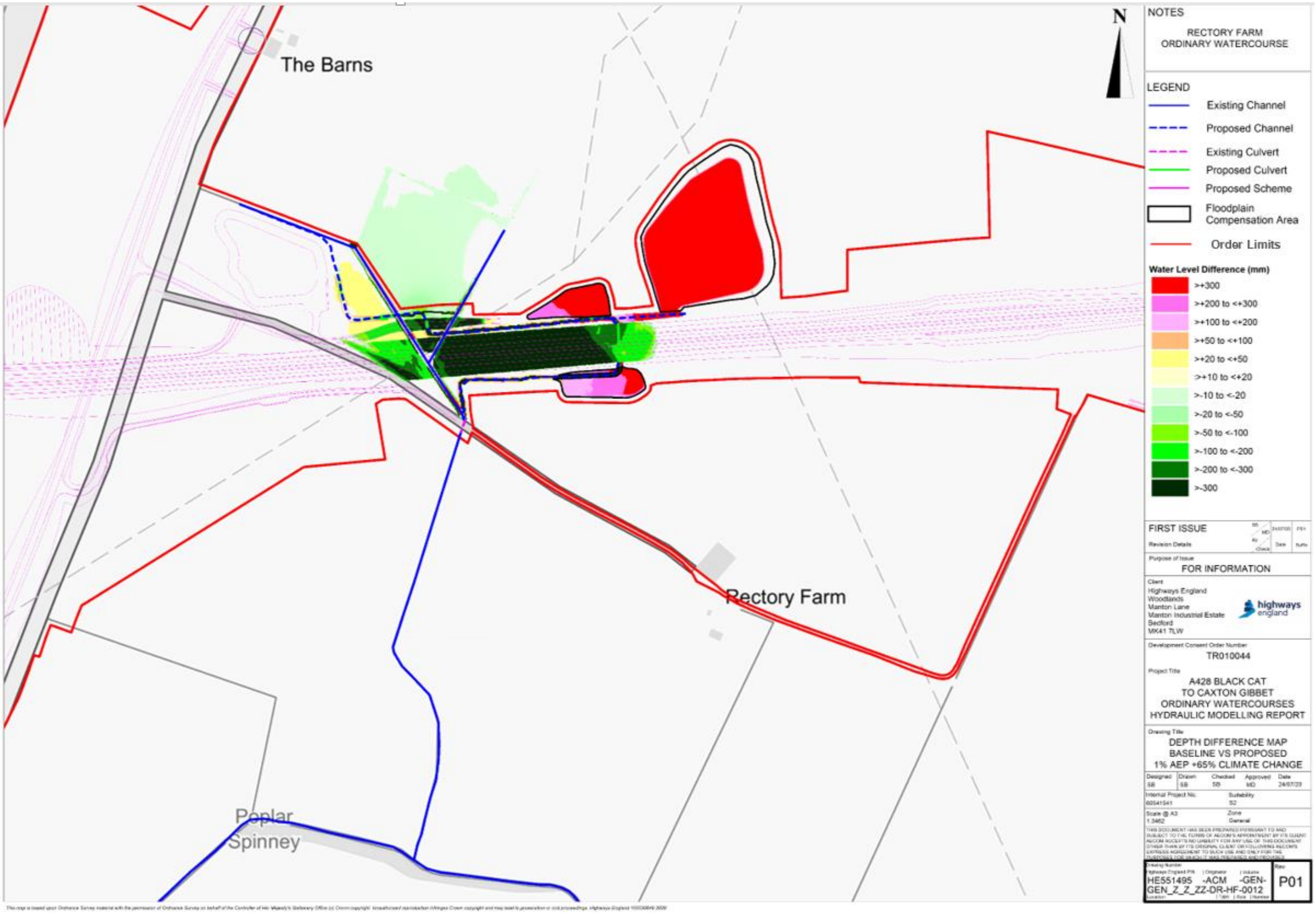

Figure 8.4 Modelled Rectory Farm 1% AEP + Climate Change (+65%) Maximum Depth Difference, Baseline vs Operational

South Brook

8.2.23 To determine the potential change in flood risk from the Scheme, once operational (as described in Section 3), hydraulic modelling has been undertaken at South Brook. Details of how the Scheme elements have been represented are included in the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA). To summarise:

a. One additional culvert has been introduced into the 1D FMP model at the location of the proposed Roxton Link Road.

b. The existing culvert beneath the A1 Great North Road has been updated based on design requirements of the Scheme.

c. Topographic amendments were applied to the 2D model to represent the new dual carriageway embankment.

d. Two online floodplain compensation areas were represented using topographic amendments to the DTM, to compensate for the floodplain storage volume lost as a result of the proposed embankment.

8.2.24 Outputs from the proposed modelling scenarios have shown that the maximum flood depths and extents for the 1% AEP +65% climate change are broadly similar downstream of the Scheme, but upstream there is a change due to the functionality of the floodplain compensation areas.

8.2.25 The areas occupied by floodplain compensation experience an increase in flood level (as expected) and this consequently causes a reduction in depths and extents in other areas upstream of the Scheme. This is reflected in Figure 8-5 which presents the maximum depth difference plot comparing the baseline and proposed scenarios.

8.2.26 Comparison of flows also indicates that there is no increase in peak flows downstream of the Scheme. This is discussed in more detail within Section 12 of Annex B of this FRA.

8.2.27 In conclusion, with informed flood mitigation upstream of the Scheme, there is no detriment to third party land.

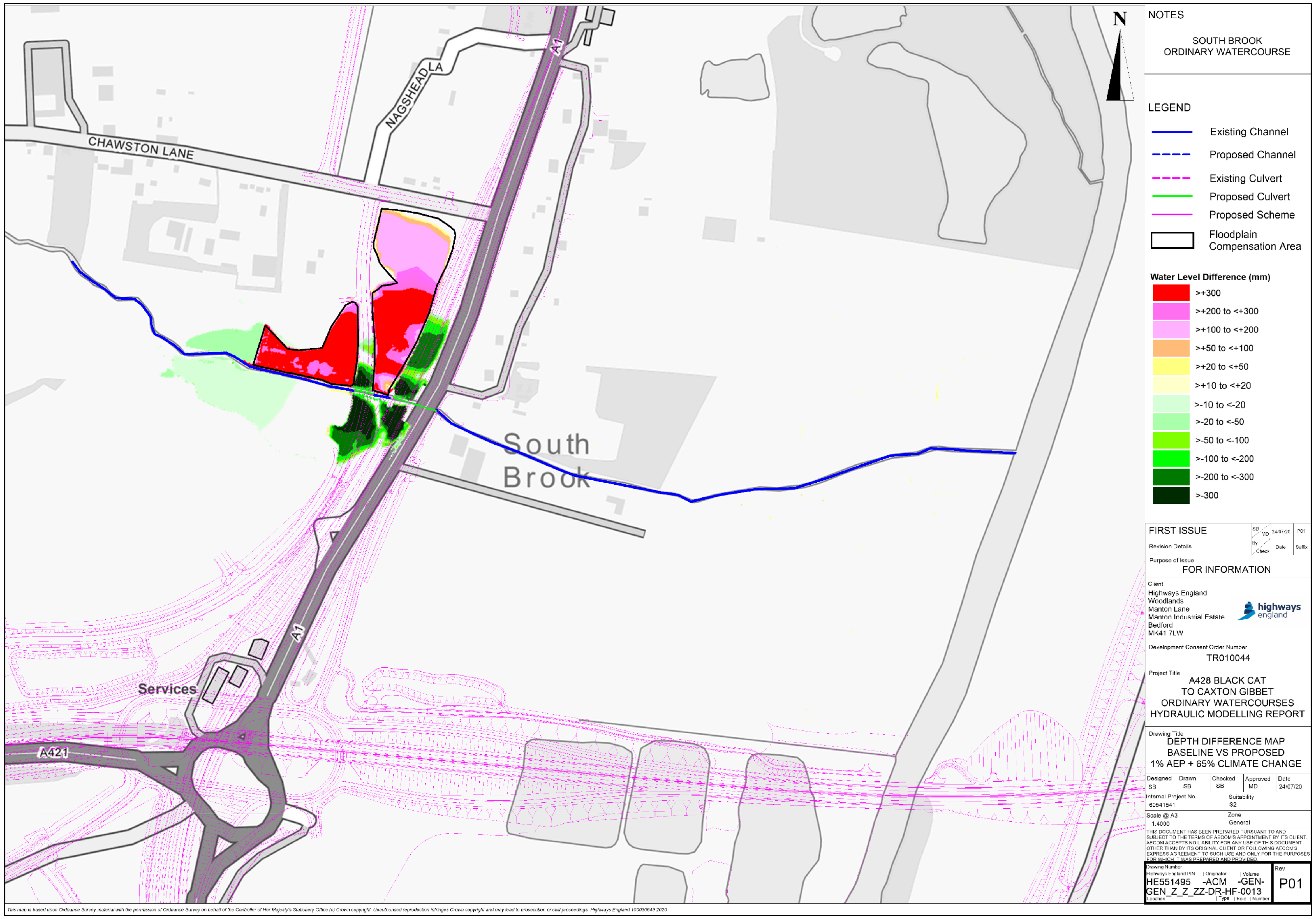

Figure 8.5 Modelled South Brook 1% AEP + Climate Change (+65%) Maximum Depth Difference, Baseline vs Operational stage

Ordinary Watercourses Represented in 1D Only

8.2.28 All other ordinary watercourses which are traversed by the Scheme have been modelled using a 1D only FMP and Micro Drainage approach. The Scheme at each of these watercourses is slightly different with a range of approaches including realigned channels, new culverts and floodplain compensation.

8.2.29 Generally, results from the FMP modelling have shown that when considering the 1% AEP +65% climate change event downstream of the Scheme there is either no change or a reduction with the in-channel flow when the proposed scenario is compared with the baseline (Table 8-1).

Table 8-1 1% AEP +65% Downstream Peak Flows

Watercourse	1% AEP +65% Downstream Peak Flow Results	
	Baseline Flow (m^3/s)	Proposed Flow (m^3/s)
West Brook	2.94	2.94
Wintringham Brook	3.55	3.55
Wintringham Brook Trib	1.32	1.32
Gallow Brook	5.10	5.08
Begwary Brook	2.71	2.70
Rockham Ditch	1.97	1.95
Top Farm Brook	3.07	3.05

8.2.30 In areas upstream of the Scheme, some models experience an increase in water level however flow remains in bank and there is therefore no increased flood risk to third parties. For more details on the modelling approach and comparison of results, please refer to Sections 3 – 9 in the Ordinary Watercourses Hydraulic Modelling Report (Annex B of this FRA of this document).

8.2.31 The assessment of flood risk from the operational stage of the Scheme has concluded that, with design mitigation, the risk to other receptors from fluvial flooding would be low.

8.3 Surface water flood risk

8.3.1 The elements of the Scheme (when fully operational) which have the potential to change surface water flood risk are:

a. *Junction upgrades*: surface water flood risk could be impacted by an increase in impermeable area.

b. *Embankments and cuttings:* introduction of variable slopes for embankments and cuttings have the potential to change overland surface water flow paths.

c. *Increased road surface:* the new impermeable surface area would increase the surface water run-off with the potential to increase flood risk on-site and further downstream by rapid discharge to receiving waterbodies.

8.3.2 As discussed in Section 6.5 of this report, the key surface water flow paths which are likely to traverse the Scheme (based on the Environment Agency's FMfSW) have been modelled as part of the fluvial assessment. It has been concluded that through appropriate mitigation, flood risk from the ordinary watercourses does not increase to sensitive receptors as a result of the Scheme and is considered to be low.

8.3.3 A detailed drainage strategy has also been produced for the Scheme to ensure that surface water is managed effectively and sustainably. Details relating to the design and results of this strategy are located within **Appendix 13.3** (Road Drainage Strategy Report) of the Environment Statement Appendices **[TR010044/APP/6.3]**.

8.4 Groundwater flood risk

8.4.1 As described in the **Appendix 13.7** Groundwater Risk Information of the Environmental Statement **[TR010044/APP/6.3]**, the potential impacts for groundwater flood risk from the Scheme during the operational stages could arise mainly from the permanent elements of the Scheme such as large underground structures like cuttings and pilings and associated bridge structures that are likely to be below the natural seasonal peak groundwater table and have the capacity to act as impermeable hydraulic barriers to alter the natural groundwater level and flow regimes.

8.4.2 Accordingly, for pilings and associated bridge structures, irrespective of their depths below the groundwater table, given their likely sizes, the potential impacts on the groundwater level and flow regimes to result in groundwater flood risk will likely be very localised as the groundwater will flow around the low permeability piles and will not affect the overall groundwater level and flow regime. Also, considering the proposed Scheme drainage design allowance for minimal groundwater flows as, mitigation measures incorporated in the Scheme's design, described in Section 5.4 of the DSR for the Scheme (**Appendix 13.3** of the Environmental Statement Appendices **[TR010044APP/6.3]**, it is unlikely that pilings and associated bridge structures will create new preferential pathways that can result in potential groundwater flood risk. Accordingly, it is considered that, with mitigation in place, the overall risk from pilings and associated bridge structures to cause groundwater flooding to other receptors during the operation of the Scheme will be low.

8.4.3 Similarly, for all the cuttings along the Scheme, as detailed in **Appendix 13.7** of the Environmental Statement Appendices **[TR010044/APP/6.3]**, a qualitative risk assessment (which considers the length and depth of each cutting below the maximum natural groundwater level while also taking into consideration the depth of the natural groundwater level below the ground elevation) indicates that the potential for groundwater flood risk to arise from the cuttings and associated retaining walls during the operational stage of the Scheme will be generally low, as the peak groundwater level at each cutting location is generally greater than (>) 2m BGL. Also, most of the cuttings fall within the areas of <25% groundwater flooding susceptibility areas as depicted from the groundwater flooding susceptibility map (AStGWF – see Section 6.5). The only exceptions are the A1 underpass cutting, Barford road cutting which were assessed to be of moderate potential groundwater flooding risk given the shallow (<2m BGL) groundwater level and the Allington Hill cutting which indicated a high potential groundwater flooding risk given the near-surface groundwater table (<1m BGL) observed in the area (see mitigation below). These three cuttings also fall within the regions indicated by the groundwater flooding susceptibility map (AStGWF – see Section 6.5) which showed a greater (>) 75% susceptibility.

8.4.4 The A1 underpass cutting, Barford road cutting and the Allington Hill cuttings indicated potential risks of groundwater flooding. Taking into consideration ground elevation profile at the locations of these three cuttings in relation to the potential identified receptors and mitigations incorporated in the design, such as but not limited to, groundwater flow path barriers, as detailed in **Chapter 13** of the Environmental Statement **[TR010044/APP/6.1]**, the groundwater flood risk to other receptors, from the cuttings and associated retaining walls, as a result of new preferential pathways during the operation of the Scheme will be low.

8.5 Sewer flood risk

8.5.1 The operational stage features would only alter one outfall from a small Anglian Water reservoir, located to the east of the new dual carriageway in the Top Farm area, which has been incorporated in the Top Farm modelling (refer to Annex B of this FRA - Ordinary Watercourse Modelling Report) and shown not to cause any adverse downstream impacts to flood risk, therefore, the risk to receptors from sewer flooding as a result of the Scheme would be low.

9 Flood risk from the Scheme – construction stage

9.1 Overview

9.1.1 This section provides an overview of the risk of flooding *from* the construction works associated with the Scheme. The flood risk from the operational stage only is addressed in Section 8.

9.2 Fluvial flood risk

River Great Ouse

9.2.1 To ensure that the impact upon flood risk during the construction phase of the Scheme was fully captured within the assessment, all temporary construction works were incorporated into a hydraulic model that included the operational stage features.

9.2.2 This configuration was considered to provide a worst-case assessment of flood risk during the construction phase as a short-term assessment. Details of how the temporary construction Scheme elements have been represented are included in Section 3 of the River Great Ouse Hydraulic Modelling Report (Annex A). To summarise:

a. A working platform set to an elevation of 16m AOD was represented within the model using topographic modifications within the 2D model.

b. Cofferdams used to construct the Scheme crossing were represented using elevation varying flow construction units.

c. Temporary access to the working platform was not considered to impact the hydraulics of the floodplain or river channel and was therefore not included within the model. Storage areas are located outside of the floodplain and are therefore excluded.

9.2.3 **Figure 9.1** presents the 1% AEP maximum water level difference plot for this operational plus construction works scenario (compared with the baseline). There is a general reduction in maximum flood depths upstream of the Scheme (outside of the Order Limits) of -10mm to -50mm with increases in flood depths confined to the proposed floodplain compensation storage area. There is no change in maximum flood depths downstream of the Scheme. It should be noted that climate change has not been considered as part of the construction works assessment due to the comparatively short timeframe associated with the construction works.

9.2.4 There are very localised increases/decreases in maximum flood level of up to 100 mm when compared to the baseline, as a consequence of the cofferdams and working platforms, in the immediate vicinity of the River Great Ouse viaduct, defined as within 50 metres upstream/downstream of the crossing. These changes occur in areas that already flood within the baseline scenario and within the Order Limits and therefore due to the localised impact would not affect any sensitive receptors.

9.2.5 When 1D in-channel maximum stage results are compared with the baseline scenario, there is no change in the maximum stage downstream of the Scheme.

9.2.6 In conclusion, model results show that the inclusion of the temporary construction works would not impact flood risk from the Scheme and the conclusions are consistent with those discussed in Section 8.2. There is no increased flood risk upstream or downstream of the Scheme outside of the Order Limits.

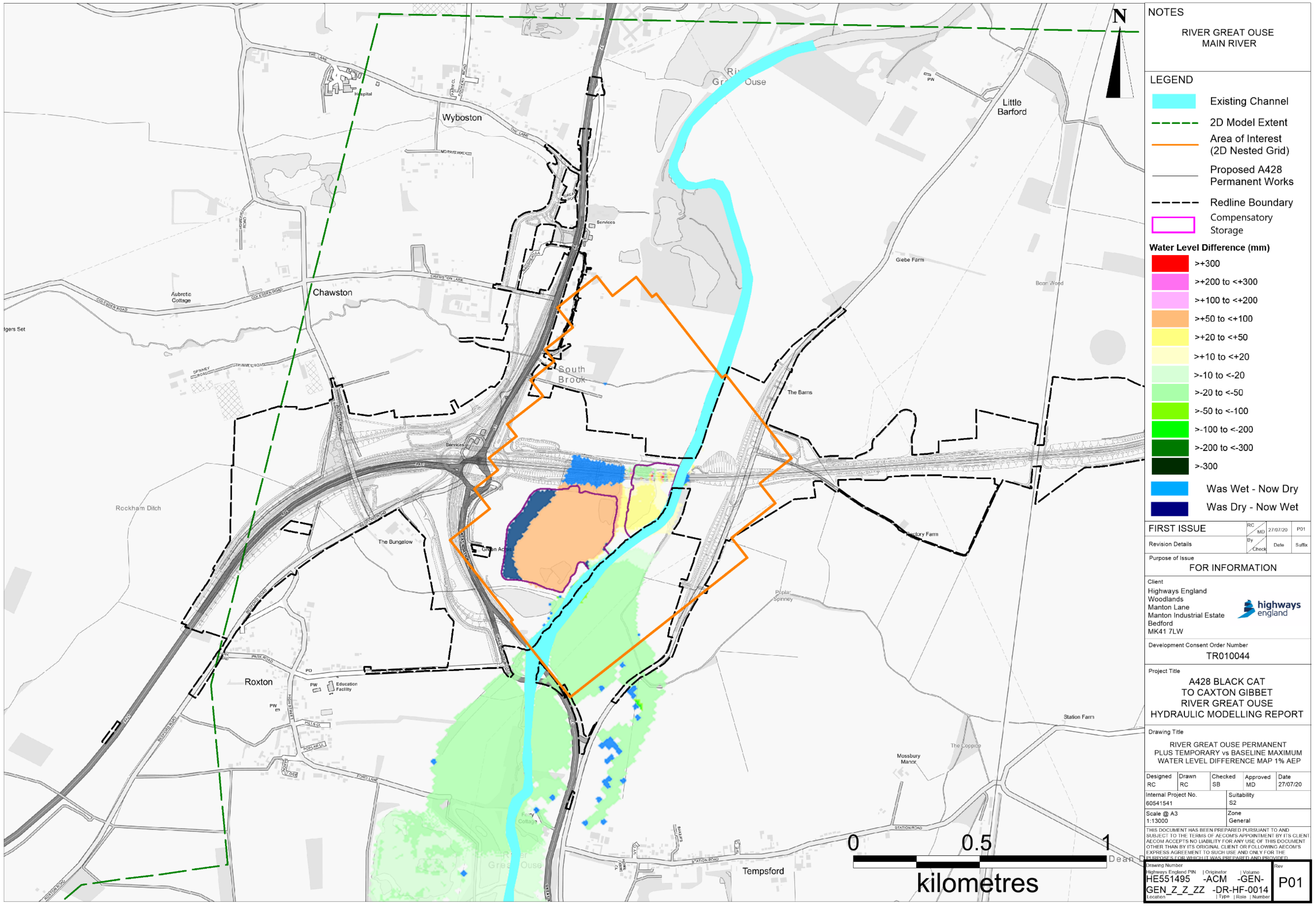

Figure 9.1 Modelled River Great Ouse 1% AEP Depth Difference Map comparing baseline with temporary construction works associated with the Scheme

Other watercourses

9.2.7 Temporary construction works will not impact ordinary watercourses, as any temporary works, that have the potential to obstruct floodplain flows, will be located outside of floodplains or appropriate flood mitigation implement by the Principal Contractor, in accordance with the Outline Water Management Plan (OWMP) (Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**) and requirement 3 of the draft DCO **[TR010044/APP/3.1]** that requires preparation of a Second Iteration EMP, which will also include consideration of flood risk.

9.2.8 The assessment concludes that fluvial flood risk from temporary construction works associated with the Scheme is considered to be low.

9.3 Surface water flood risk

9.3.1 The temporary construction Scheme elements which have the potential to alter surface water flooding are site compounds, due to an increase in impermeable area.

9.3.2 Surface water and Scheme elements which will result in an increase in impermeable area will have design mitigation incorporated. Site compounds will be designed to manage surface water runoff so there is no increase in surface water flooding to other receptors, in accordance with the Outline Water Management Plan (OWMP), Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**.

9.3.3 The risk to receptors from surface water flooding as a result of the temporary construction works associated with the Scheme would be low.

9.4 Groundwater flood risk

9.4.1 As described in the **Appendix 13.7** Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**, the potential for groundwater flooding risks to arise from the Scheme during construction are mainly associated to areas with deep excavation such as cuttings and borrow pits that are likely to alter groundwater level, flow and drainage regimes and with potential associated temporary dewatering activities.

9.4.2 The potential receptors and their level of sensitivity, including the pathways present or that could potentially be created by the Scheme, are detailed in Section 5 of **Appendix 13.7** of the Environmental Statement Appendices **[TR010044/APP/6.3]**.

9.4.3 To determine the potential impacts of the temporary construction Scheme elements on the groundwater flood risk, the source-pathway-receptor linkages have been identified along the Scheme, through a review of the hydrogeological conceptual model, referred to in Section 5 of this report.

9.4.4 The source-pathway-receptor linkages identified with respect to the potential impact on the groundwater flood risk from temporary construction elements have been assessed in detail at Section 5 in the Appendix 13.7 Groundwater Risk Information of the Environmental Statement Appendices **[TR010044/APP/6.3]**.

9.4.5 It is anticipated that any potential impacts on groundwater level and flow regimes from construction activities (such as cuttings, groundwater abstraction for dewatering purposes or the use of cofferdams/hydraulic barriers to facilitate the construction of the Scheme) that can result in potential risks of groundwater flooding will be temporary and localised. Measures to prevent or reduce the risk of groundwater flooding during construction, will be incorporated in line with best practice construction methods and in accordance with the Outline Water Management Plan (OWMP), (Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**.

9.4.6 Based on the above and following the implementation of embedded mitigation, the groundwater flood risk to receptors resulting from the impact of temporary construction works would be low.

9.5 Sewer flood risk

9.5.1 There will be no impact on the sewer flood risk from the temporary construction works, within the Order Limits, given the predominantly rural nature of the study area and modelling check described in Section 8.5, therefore; the sewer flood risk to receptors would be low

10 Summary and conclusions

10.1 Key flood risk sources

10.1.1 The main flood risk sources within the study area are fluvial, surface water and groundwater. The risk from sewer flooding is localised given the limited extent of any sewers within the study area.

10.1.2 The majority of the study area is located within Flood Zone 1 (low probability) except where the Scheme traverses the River Great Ouse and ordinary watercourses (Hen Brook, South Brook, Rectory Farm, Begwary Brook and Wintringham Brook) where areas of Flood Zone 2 and 3 are present.

10.1.3 The majority of surface water flood risk in the study area is categorised as 'Very low'; with some areas categorised as 'Low', 'Medium' and 'High' which represent flowpaths associated with the ordinary watercourses.

10.1.4 The risk of groundwater flooding is considered to be low in the vast majority of the study area with the only exception of the western part of the Scheme where the potential for groundwater flooding risk is considered to be high due to the shallow groundwater conditions and the potential for groundwater-surface water interaction in the floodplain of the River Great Ouse.

10.1.5 The new 10 mile (16 kilometres) dual 2-lane carriageway from the Black Cat roundabout to Caxton Gibbet roundabout will not be impacted by fluvial, over land surface water, sewer, reservoir or groundwater flooding during the1% AEP +65% climate change design storm event. . Due to this conclusion, there is no further requirement to consider safe access and egress as part of this FRA for the dual carriageway.

10.2 Flood risk to the Scheme – operational stage

Fluvial flood risk

10.2.1 The Scheme elements (when fully operational) at risk of fluvial flooding include:

a. The piers of the River Great Ouse viaduct located within the 1% AEP flood extent.

b. The new dual carriageway embankment which traverses the River Great Ouse and ordinary watercourses.

c. The access tracks which serve the surface water drainage ponds.

10.2.2 To mitigate potential impacts to the Scheme the new dual carriageway will either be located outside of the flood extent, or raised appropriately to prevent inundation during the design flood event. To compensate for this loss of floodplain, compensatory storage is being provided throughout the study area to prevent increased flood risk to both the Scheme and third party land. The pier foundations for the River Great Ouse viaduct will be designed to withstand fluvial flood flows interacting with the piers.

10.2.3 In some locations (Hen Brook and Rectory Farm) small sections of the proposed access routes to surface water ponds are shown to be within the floodplain. These are not considered key routes which will be frequently used and will be avoided during a large flood event.

10.2.4 With design mitigation, the risk to the Scheme from fluvial flooding is considered to be low.

Surface water flood risk

10.2.5 With the Scheme traversing a number of surface water flow paths associated with ordinary watercourses there is potential for the Scheme to be at risk of surface water flooding without appropriate mitigation.

10.2.6 At the location at which the Scheme traverses the ordinary watercourse, culverts are being designed to maintain existing flows based on the 1% AEP +65% climate change event. Attenuation ponds are also being provided to ensure that surface water flood risk is not increased to the proposed highway or to sensitive receptors.

10.2.7 The new dual carriageway is being designed to minimise the risk of flooding by incorporating current design standards and future climate change allowances to improve its resilience using sustainable drainage techniques. Information on the overall drainage strategy and associated attenuation ponds is presented within **Appendix 13.3** (Road Drainage Strategy Report) of the Environmental Statement Appendices **[TR010044/APP/6.3]**.

10.2.8 With design mitigation, the risk to the Scheme from surface water flooding is considered to be low.

Groundwater flood risk

10.2.9 As discussed in Section 7.4, given the mitigation measures incorporated in the Scheme's design, the overall potential groundwater flooding risk to the Scheme is considered to be low.

Sewer flood risk

10.2.10 The risk of sewer flooding, to the Scheme, once fully operational, is considered to be low, given the rural nature of the study area and mitigations incorporated in the drainage strategy for the potential risk of flooding that may be caused by the drainage network being unable to discharge due to high water levels.

10.3 Flood risk from the Scheme – operational stage

Fluvial flood risk

10.3.1 The Scheme elements (when fully operational) which have the potential to alter fluvial flooding are:

a. The introduction of a new dual carriageway embankment which has the potential to alter flood flow pathways associated with the River Great Ouse and ordinary watercourses.

b. The introduction of piers into the River Great Ouse floodplain which has the potential to interrupt flood flows and create a local backwater effect.

10.3.2 When considering the 1% AEP +35% climate change event for the River Great Ouse (1D-2D model), maximum water elevations increase (as intended) within the compensatory areas and intuitively, flooding is removed where the new dual carriageway embankment crosses the floodplain. There is also a general reduction in maximum water levels outside of the Order Limits, upstream of the Scheme.

10.3.3 It is noted that there is an increase in maximum flood depths on the right bank of the River Great Ouse upstream of the Scheme immediately outside of the Order Limits of +10mm to +50mm. This occurs in agricultural areas which already flood to a depth greater than 1m during the 1% AEP +35% climate change event. It is considered that these increases can easily be eliminated in the detailed design phase by adjusting design parameters such as viaduct or flood compensation earthwork slopes and minor modelling parameters to optimise overall hydraulic results and will remain within the Order Limits.

10.3.4 When considering the 1% AEP +65% climate change event for Hen Brook (1D-2D model), maximum water elevations increase (as intended) within the compensatory areas and intuitively, flooding is removed where the new dual carriageway embankment crosses the floodplain. There is a decrease in flood depths immediately upstream and downstream of the Scheme (-600mm) which is attributable to the compensation areas.

10.3.5 Overall, the modelling results have shown that with mitigation in place, the Scheme does not have a significant impact on channel flow downstream or flood depths and levels on the floodplain.

10.3.6 When considering the 1% AEP +65% climate change event for Rectory Farm (1D-2D model), maximum water elevations increase (as intended) within the compensatory areas and intuitively, flooding is removed where the new dual carriageway embankment crosses the floodplain. There are a few isolated areas where flood depths increase (+36mm) as a result of the Scheme however these are all located within the Order Limits.

10.3.7 When considering the 1% AEP +65% climate change event for South Brook (1D-2D model), maximum water elevations increase (as intended) within the compensatory areas and intuitively, flooding is removed where the new dual carriageway embankment crosses the floodplain. These compensation areas also cause a reduction in flood extents upstream of the Scheme while downstream there is a negligible impact.

10.3.8 For the ordinary watercourses which were modelled in 1D only, results for the 1% AEP +65% climate change event have shown that the Scheme has a negligible impact on downstream level and flow. Some watercourse experienced an increase with the in-channel water level however flow remains in-bank and therefore will not affect the Scheme Order Limits.

10.3.9 The assessment of flood risk from the operational stage of the Scheme has concluded that with design mitigation, the risk to other receptors from fluvial flooding would be low.

Surface water flood risk

10.3.10 Hydraulic modelling undertaken has shown that with design mitigation, surface water flood risk does not increase for sensitive receptors as a result of the Scheme and is considered to be low. The design mitigation is detailed within Appendix 13.3 (Road Drainage Strategy Report) of the Environment Statement Appendices **[TR010044/APP/6.3]**.

Groundwater flood risk

10.3.11 As discussed in Section 8 of this report, some permanent elements of the Scheme such as cuttings, retaining walls, borrow pits, pilings and associated bridge structures are likely to intercept the seasonal groundwater table which can alter the groundwater level and flow regimes resulting in potential groundwater flood risk.

10.3.12 However, given the ground elevation profile in relation to the potential identified receptors and mitigation measures incorporated in the Scheme's design, the overall potential groundwater flooding risk from the Scheme is considered to be low.

Sewer flood risk

10.3.13 The operational stage features would only alter one outfall from a small Anglian Water reservoir, addressed in Section 8.5, however, as proven by modelling results and due to the predominant rural nature of the study area, the risk to receptors from sewer flooding as a result of the Scheme is considered to be low..

10.4 Flood risk from the Scheme – construction stage

Fluvial flood risk

10.4.1 The temporary construction Scheme elements at the River Great Ouse that have the potential to alter fluvial flood risk include:

a. A working platform set to an elevation of 16m AOD

b. Cofferdams used to construct the Scheme crossing

10.4.2 When considering the 1% AEP event, there is a reduction in maximum flood depths upstream of the Scheme (up to -50mm) when the baseline and operational stage plus temporary scenarios are compared. There is no change downstream with the only increase in flood depth occurring within the floodplain compensation areas (as intended).

10.4.3 There are localised increases/decreases in the maximum flood level associated with the cofferdams and working platforms but these are negligible in the context of the floodplain.

10.4.4 Temporary access to the working platform was not considered to impact hydraulics of the floodplain or river channel as they will not obstruct floodplains and was therefore excluded from the model. Storage areas are to be located outside of the floodplain and are therefore not represented.

10.4.5 The fluvial flood risk from temporary construction works associated with the Scheme is considered to be low.

Surface water flood risk

10.4.6 The Scheme elements such as site compounds that will result in an increase in impermeable area have the potential to alter surface water flooding and will therefore have design mitigation incorporated. Site compounds will be designed to manage surface water runoff so there is no increase in surface water flooding to other receptors, in accordance with the Outline Water Management Plan (OWMP), (Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**.

10.4.7 The risk to receptors from surface water flooding as a result of the temporary construction works associated with the Scheme is considered to be low.

Groundwater flood risk

10.4.8 As discussed in Section 9, temporary construction works, such as cofferdams and other temporary impermeable barriers and the discharge of groundwater from dewatering activities can have the potential to alter groundwater levels and flow regimes which can result in potential groundwater flood risk from the Scheme especially in the existing Black Cat roundabout area, west of the study area.

10.4.9 However, given the mitigation measures incorporated in the Scheme's design and the Outline Water Management Plan (OWMP), (Annex F of the First Iteration Environmental Management Plan **[TR010044/APP/6.8]**), the overall potential groundwater flood risk from the Scheme is considered to be low.

Sewer flood risk

10.4.10 The temporary construction works associated with the Scheme do not impact sewer flood risk, therefore the sewer flood risk from the temporary construction works would be low.

10.5 Sequential and exception test

10.5.1 It is considered that there will be no significant increase in fluvial flood risk to the neighbouring land uses, or an increase in surface water runoff as a result of the Scheme based on application of identified mitigation measures.

10.5.2 The Scheme alignment passes through Flood Zone 3, and therefore does not automatically pass the Sequential test. Owing to the nature of the Scheme, it is not viable to relocate the works in a zone with a lower probability of flooding, especially with regards to the River Great Ouse crossing. In order to connect the Black Cat roundabout to the Caxton Gibbet roundabout, the River Great Ouse must be crossed. The Scheme alignment has been developed following a comprehensive assessment of different alignment options, which considered all environmental impacts (inclusive of flood risk). The Scheme is classed as Essential Infrastructure and passes through Flood Zone 3. Therefore, the Scheme must be assessed against the Exception Test.

10.5.3 For the Exception Test to be passed the development must demonstrate that:

a. It provides wider sustainability benefits to the community that outweigh flood risk.

b. It will be safe for the lifetime of the development.

10.5.4 To satisfy the Exception Test, hydraulic modelling has been developed to assess the flood risk to and from the Scheme where it resides in Flood Zone 3. Overall the modelling results demonstrated that there is no significant impact on flooding once the Scheme is operational and during the construction stage, however; instances where there are increases in maximum flood depths and levels associated with the Scheme are clearly detailed within this FRA and in Annexes A, B and C of this report.

10.5.5 Since the Scheme is also classed as a Nationally Significant Infrastructure Project (NSIP), it is considered that the Exception Test is satisfied in terms of the benefits to the community and safety. The evidence of the Scheme's wider sustainability benefits to the community is set out in Chapter 4 of the Case for the Scheme **[TR010044/APP/7.1]**. The information presented within this report demonstrates that mitigation measures have been incorporated into the design to ensure that the new road will be at a low risk of flooding and will be safe for the lifetime of the development.

10.6 Conclusion

10.6.1 It is concluded that the flood risk *to* and *from* the operational and construction stages of the Scheme from fluvial, surface water, groundwater and sewer flooding, is considered to be low.

10.6.2 When considering fluvial flood risk associated with the River Great Ouse and ordinary watercourses, any changes to modelled flood depths are limited to areas of agricultural land or undeveloped green space. Where increases and decreases in flood depth occur, the majority of these occur in areas which are already at risk of flooding and the changes in flood depth do not increase flood risk because they do not coincide with sensitive receptors such as residential and commercial property.

10.6.3 Where increases in flood depth are reported, given the minor localised increases, these are either located within Order Limits or can be designed out during the detailed design modelling phase as specified for each case in the sections above .

11 References

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Annex A River Great Ouse Hydraulic Modelling Report

Annex B Ordinary Watercourses Hydraulic Modelling Report

Annex C Ordinary Watercourse Hydrology Report