M11 Junction 7A

Ringway Jacobs / Essex County Council

Flood Risk Assessment Report: Detailed Assessment

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M11 Junction 7A

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Jacobs U.K. Limited

1 City Walk
Leeds, West Yorkshire LS11 9DX
United Kingdom
T +44 (0)113 242 6771
F +44 (0)113 389 1389
www.jacobs.com

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Executive Summary

Essex County Council, Major Programmes and Infrastructure (ECC) is developing a proposal for the provision of a new motorway junction (Junction 7A) on the M11 between the existing Junctions 7 and 8, a proposed link road to Sheering Road (B183) linking the M11 to Harlow, and proposed widening and improvement works to Sheering Road / Gilden Way (B183), together known as the 'scheme'.

On behalf of Ringway Jacobs and ECC, Jacobs UK Ltd has been commissioned to undertake a Flood Risk Assessment (FRA) as part of the Environmental Impact Assessment (EIA) of the scheme prepared in support of a Planning Application. The FRA assesses the flood risk to the scheme and the impacts on flood risk and drainage post-development in accordance with the National Planning Policy Framework (NPPF) and local policies of Harlow District Council (HDC) and Epping Forest District Council (EFDC).

The scheme is located within the River Stort catchment. The main tributaries within the 1km study area are the Pincey Brook and the Harlowbury Brook, both of which are designated as Main River watercourses. The Harlowbury Brook is crossed by the B183 at Gilden Way Bridge on the outskirts of Harlow. There is also a small un-named tributary of the Pincey Brook that is part culverted beneath arable land at its downstream section. The un-named watercourse from the wooded area known as The Mores is designated an Ordinary Watercourse.

Based on the Environment Agency's (EA) indicative Flood Map the study area is located largely within Flood Zone 1. There are areas in Flood Zones 2 and 3 adjacent to the Pincey Brook and the Harlowbury Brook. Where the B183 crosses the Harlowbury Brook the road is shown to be within the floodplain.

Jacobs undertook further fluvial modelling of the Pincey Brook and the un-named tributary. The modelling indicates that the proposed new junction and proposed link road are located outside of the modelled 0.1% Annual Exceedance Probability (AEP) flood extent. Where the proposed link road intersects the un-named watercourse, culverts are proposed to convey flood flow. Similarly, publically accessible reporting of fluvial modelling of the Harlowbury Brook, as prepared by WSP, considered the location where Harlowbury Brook is crossed by the B183 at Gilden Way Bridge. The floodplain extent both immediately upstream and downstream of Gilden Way Bridge is also reported as being significantly less than that indicated by the EA Flood Map. There are no proposed works to Gilden Way Bridge within the scheme, and all proposed highway works will be located within the existing highway boundary.

An appropriate drainage strategy will be incorporated into the scheme to reduce the increased risk from surface water flooding as a result of the introduction of additional impermeable areas. With due regard to the drainage hierarchy and consultation with ECC, it is proposed to attenuate highway runoff in four strategically located attenuation systems comprising ponds, tanks and oversized pipework to achieve controlled discharge to watercourses based on either a 1 in 1 year greenfield rate and/or appropriately reduced rates compared to the existing 1 in 1 year 'brownfield' (from existing contributing areas) rates. The ponds will be lined to protect underlying aquifers and prevent potential ingress of shallow groundwater, and planted with vegetation to aid water treatment.

The assessment carried out has concluded that, if the mitigation measures outlined are adopted, the scheme will not be at significant risk of flooding from any source and will not increase the flood risk elsewhere. The proposed development is, therefore, considered compatible with existing flood risk and in accord with national and local policy.

1. Introduction

1.1 Objective

Essex County Council, Major Programmes and Infrastructure (ECC) is developing a proposal for the provision of a new motorway junction (Junction 7A) on the M11 between the existing Junctions 7 and 8, a new link road to Sheering Road (B183) linking the M11 to Harlow, and widening and improvement works to Sheering Road/Gilden Way (B183), together known as the 'scheme'.

A Flood Risk Assessment (FRA) has been undertaken for the scheme in support of the planning application. The aim of this FRA is to determine whether the proposed development is safe from flooding and that it will not increase the flood risk elsewhere. In order to do this the FRA process takes into account the following policies:

- National Planning Policy Framework (NPPF);
- Planning Practice Guidance (2014); and
- Essex Country Council and Harlow District Council (HDC) Local Development and Planning Policies.

The objectives of this FRA are to:

- Provide an overview of the relevant flood risk policies and set out how they apply to the development;
- Assess the sources of flood risk at the development site; and
- Set out the measures incorporated in the design of the development to mitigate any residual risk from all sources of flooding.

It should be noted that this FRA is for planning purposes only and will support the ECC's Environmental Impact Assessment for the proposed scheme. The FRA has been undertaken as the overall development area is greater than 1 hectare.

1.2 Sources of information

The following key sources of information have been used in this assessment:

- NPPF (DCLG, 2012) and accompanying online Planning Practice Guidance (DCLG, 2015);
- Adopted Replacement Harlow Local Plan (HDC, 2006);
- Combined Policies of Epping Forest District Local Plan (1998) and Alterations (2006) (EFDC, 2008);
- Local Flood Risk Management Strategy (ECC, 2013);
- Preliminary Flood Risk Assessment (ECC, 2011);
- Level 1 Strategic Flood Risk Assessment (SFRA) (HDC & EFDC, 2011);
- Harlow Surface Water Management Plan (SWMP) (Capita Symonds, 2013);
- Contemporary Ordnance Survey (OS) maps;
- M11 Junction 7A Topographic Surveys (Jacobs UK Ltd, 2014 to 2016)
- EA Flood Risk and Groundwater mapping (2015);
- British Geological Survey (BGS) online mapping (2015);
- M11 Junction 7A Ground Investigation Report (Jacobs UK Ltd, 2016);
- Thames Water Asset Location Plan and Sewer Flood History Report;
- Affinity Water Asset Management Plan; and
- M11 Junction 7A Drainage Design – Concept Development Note (Jacobs UK Ltd, 2016).

2. Scheme Description and Proposal

2.1 Scheme location

The proposed scheme is located in the west of Essex County, east of Harlow between the existing Junctions 7 and 8 of the M11. The proposed location of Junction 7A is centred at approximate National Grid Reference 549800, 212300.

The scheme extends westwards from the new junction, through rural land before joining the existing Sheering Road (B183) to the north of The Campions. The B183 continues westwards towards Harlow, becoming Gilden Way (North) prior to Churchgate Roundabout and Gilden Way (South) after crossing Harlowbury Brook. The terminus of the scheme is London Road Roundabout prior to the A414. Existing characteristics of the scheme location are described in Sections 2.3 to 2.9 below.

The study area adopted for water environment aspects of the EIA and the location of the proposed scheme are shown as Figure 1.

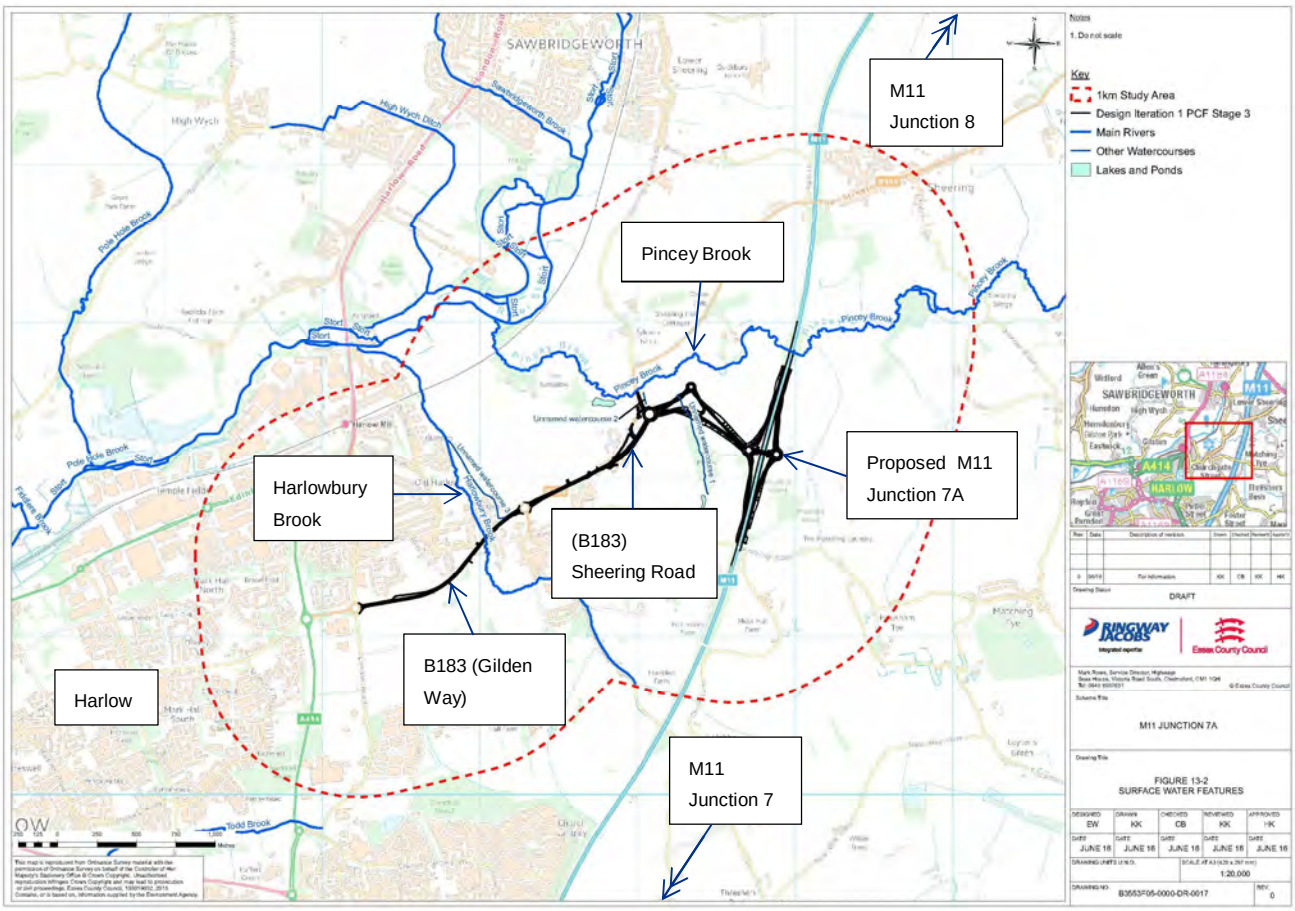

Figure 1: Water environment study area and proposed scheme

2.2 Proposal

The proposed scheme comprises the following elements:

- New grade separated junction consisting of an overbridge and roundabouts above the existing M11 motorway;

- New slip roads mostly on embankment to the north of the new junction;
- New slip roads mostly in cutting to the south of the new junction;
- Roundabouts connecting the motorway to the existing B183 Sheering Road/Gilden Way in the west. The new link is approximately 1 km long and comprises carriageways on separate embankments;
- Re-routed and culverted section of un-named Ordinary Watercourse (from the wooded area known as The Mores – see Section 2.5) discharging to Pincey Brook; and
- Approximately 2km of improvement works along Gilden Way (B183), from the general area of Mayfield Farm to its junction with London Road Roundabout in the west.

Works on Gilden Way comprise widening of the existing carriageway by approximately 2.6m to create an additional lane, and road surface improvement works. Surface improvement works comprise the addition of up to approximately 250mm of road material (approximately 100mm at Gilden Way Bridge). All carriageway works are within the highway corridor of the original Gilden Way. There are no proposed works to the Gilden Way Bridge over the Harlowbury Brook. There are also no proposals to modify the configuration and dimensions of Gilden Way Bridge; however, the condition of the existing structures is in the process of being assessed.

2.3 Existing land use

The land use of the scheme area is a mix of rural agricultural and Green Belt land to the east, and sub-urban areas on the outskirts of Harlow to the west. The east of the area is typically characterised by arable land, farmsteads and small settlements including The Campions and Mayfield Farm to the north and south of the Sheering Road respectively. Further to the west, on the approach to Harlow, the land use includes a residential estate and sports pitches to the south of Gilden Way. After Churchgate Roundabout, and to the north of Gilden Way is the residential area of Old Harlow.

2.4 Existing topography

Topographic levels are generally quoted from site-specific topographic survey work to metres Above Ordnance Datum (AOD). Where the survey work does not cover the full extent of the scheme area, levels are approximated from OS mapping.

The M11 motorway falls from south to north by approximately 8.5m, from 77.14m AOD at the Moor Hall Road bridge crossing to approximately 68.66m AOD at the point where the proposed new junction is located. The M11 continues to fall northwards to 59.00m AOD where the motorway crosses the culvert carrying Pincey Brook. The motorway then rises to approximately 77m AOD at the Harlow Road and bridge crossing at the northern extent of the study area (based on OS mapping). The M11 lies in cutting in the south of the area, with the embankment on both sides approximately 2m higher than the road. The motorway then rises on embankment over Pincey Brook.

Land within the study area generally falls from the motorway to the northwest and southwest towards Pincey Brook and Harlowbury Brook respectively. Harlowbury Brook traverses the study area from southeast to northwest and is effectively culverted beneath Gilden Way. Where the proposed scheme joins Sheering Road to the west, the existing road is located at approximately 49.08m AOD. Sheering Road (becoming Gilden Way (North)) then rises to approximately 53.19m AOD at Churchgate Roundabout before falling to 50.46m AOD where Gilden Way crosses Harlowbury Brook. From the low point in the vicinity of Gilden Way Bridge and the existing pedestrian underpass the road then rises to the west into Harlow.

2.5 Existing hydrology

There are two Main Rivers in close proximity to the scheme namely, Harlowbury Brook in the south and Pincey Brook to the north. Both of these watercourses are rural upland tributaries of the River Stort. The River Stort is located to the north of the proposed scheme and largely outside of the study area. The River Stort flows in a northeast to southwest direction to the River Lea in Hoddesdon, approximately 9.7km to the west.

Harlowbury Brook rises to the east of Newhall and Church Langley and to the south of Gilden Way. To the north of Gilden Way Harlowbury Brook flows northwards through the residential area of The Oxleys and then beyond the study area where it joins the River Stort at a location approximately 1.5km downstream of Gilden Way. There are two crossings of this brook within the study area. The first under Gilden Way Bridge via a 4.5m wide x 1.8m deep concrete box culvert approximately 23m in length. At this point the Harlowbury Brook serves a catchment area of approximately 7km^2. Immediately upstream of and adjacent to this bridge is the old road bridge, a 3.8m wide x 1.2m deep concrete box culvert in combination with a 13m long profiled steel soffit. There are several ditches and ponds located in the study area. There are also ponds approximately 130m to the north of Campions and a 115m to the south of Gilden Way at The Nursery.

The Pincey Brook rises close to Stansted Airport approximately 10km to the northeast of the scheme where it flows southwards then westwards towards the M11. The Pincey Brook passes beneath the M11 east to west approximately 600m to the north of the proposed new junction. At this point the Pincey Brook serves a catchment area of approximately 52km^2. The Pincey Brook continues to flow in a westerly direction, in a position to the north of the proposed link road. It eventually flows beneath the railway line (between Harlow Mill and Sawbridgeworth stations) and then into the River Stort.

A small un-named Ordinary Watercourse, a tributary of the Pincey Brook originates from a wooded area called The Mores (to the south of the proposed link road, and east of the proposed junction). The tributary serves a catchment area of approximately 0.7 km^2. Approximately 140m of the downstream section of this watercourse appears to be culverted in twin (circa 300mm diameter) pipes prior to their outfall into the Pincey Brook. At the time of survey, one of the 300mm diameter pipes was observed to be not in operation, assumed blocked.

For further information regarding Hydrology of Pincey Brook, please refer to the Pincey Brook Design Flood Hydrology Report (Appendix D).

2.6 Existing geology

Online mapping, available archive data and the Jacobs' Ground Investigation Report (GIR) dated May 2016 have been assessed to determine the existing geology of the site. Table 2.1 below summarises the general natural geological succession confirmed during the ground investigations. The geological characteristics have been taken from the GIR.

Table 2.1: Study area geological characteristics[1]

Geological Classification	Geological Unit	Geological Characteristics	Thickness (m)
Superficial	Alluvium	Very soft to soft CLAY with varying proportions of silts, sands and gravels	1.3 – 3.1
	Head Deposits	Soft to firm slightly gravelly, sandy and silty CLAY	0.3 – 5.2
	Lowestoft Formation	Firm to stiff sandy, silty, gravelly CLAY	0.3 – 42.7*
	Glaciofluvial Deposits	Loose fine to medium dense SAND and loose to medium dense GRAVEL	0.3 – 10.7
Bedrock	London Clay Formation	Firm to stiff fissured greyish brown and brown silty CLAY	0.8 – >17.6
	Thanet Sand Formation and Lambeth Group	Gravelly fine to medium SAND, very stiff friable greyish brown and dark brown possibly interlaminated clayey SILT	Proven to 3.10
	Lewes Nodular Chalk	Only encountered during previous ground	Proven to 59.4

[1] Jacobs' Ground Investigation Report (GIR) uses geotechnical information provided from the recent ground investigation carried out by Soils Ltd between 2015/16, as well as information from previous factual and interpretative reports for the study area

	Formation and Seaford Chalk Formation	investigation	

**Includes up to 4.8m of interbedded Glaciofluvial Deposits*

The scheme area, including the proposed link road and Gilden Way, are primarily underlain by the Lowestoft Formation. Glaciofluvial deposits are located within and beneath the Lowestoft Formation, particularly in the west of the study area. The Pincey Brook channel and parts of the floodplain are underlain by Alluvium deposits. The wider floodplain is underlain by Head Deposits, as is the un-named watercourse and the Harlowbury Brook. There are also other isolated pockets of Head Deposits within the scheme area.

The bedrock geology within the Pincey Brook and Harlowbury Brook catchments primarily consists of the London Clay Formation (clay, silt and sand). However, in the immediate vicinity of the proposed link road and Gilden Way there is a variety of bedrock geology including the Thanet Sand Formation and Lambeth Group, and the Lewis Nodular Chalk Formation and Seaford Chalk Formation.

The majority of the proposed new link road between the M11 and B183 is to be located on the London Clay Formation. An approximate 400m long road segment north of Churchgate Roundabout and an approximate 400m long road segment in the vicinity of London Road Roundabout are located above the Thanet Sand Formation. The road segment between Churchgate Roundabout and London Road Roundabout is located above the Lewes Nodular Chalk and Seaford Chalk (undifferentiated) Formations.

2.7 Existing hydrogeology

Hydrogeological information has been obtained from the Environment Agency's (EA) online Groundwater mapping.

The study area is predominately underlain by a *Secondary (undifferentiated)* aquifer. These are assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type. The exceptions are the areas of Alluvium, Head and Glaciofluvial deposits, which are designated as *Secondary A* aquifers. These are defined as permeable layers capable of supporting water supplies at a local, rather than strategic, scale and in some cases forming an important source of base flow to rivers (formerly known as minor aquifer).

The London Clay is non-productive strata therefore has no designated aquifer status. The Thanet Sand Formation is classified as *Secondary A* aquifer. The Lewes Nodular Chalk is classified as a *Principal* aquifer. These are defined as layers of rock or drift deposits that have high intergranular and/or fracture permeability meaning that they usually provide a high level of water storage and may support water supply and/or river base flow on a strategic scale (formerly known as major aquifer).

The EA's online Groundwater mapping also shows the vulnerability of groundwater in superficial rocks and underlying bedrock at a location based on the hydrological, geological, hydrogeological and soil properties within a one kilometre square grid. The main purpose of these maps is to provide key evidence for an assessment of the exposure of groundwater to a pollution hazard. By doing so, the vulnerability classifications infer (to an extent) the permeability of underlying strata, as follows:

- High: Areas able to easily transmit pollution to groundwater. They are characterised by high leaching soils and the absence of low permeability drift deposits.
- Medium: Areas that offer some groundwater protection. Intermediate between high and low vulnerability.
- Low: Areas that provide the greatest protection to groundwater from pollution. They are likely to be characterised by low leaching soils and/or the presence of low permeability drift deposits.

The proposed link road intersects a Minor Aquifer Intermediate at The Mores woodland and The Campions (associated with Head). Gilden Way intersects a combination of Minor Aquifer Intermediate, Major Aquifer

Intermediate and, at the far western extent close to London Road Roundabout, a Major Aquifer High (associated with a combination of Head and Chalk).

Based on the EA's online mapping, the proposed route of the highway does not lie within any groundwater source protection zone (SPZ). The nearest SPZ is located to the northwest of the study area with the outer zone (Zone 2) located approximately 1.5km from the proposed route.

The EA's Groundwater Contour Map (contained within Appendix A) illustrates the groundwater contours at a depth of 30m below ground level (bgl) under The Mores and reducing in depth until the groundwater reaches approximately 8m bgl near the Pincey Brook.

Groundwater strikes were recorded within the Lowestoft Formation (between 1.2m bgl to 19m bgl), Glaciofluvial Deposits (1.1m bgl to 22.5m bgl) and London Clay Formation (24m bgl) during the ground investigation carried out between October and December 2015.

Groundwater standpipes were installed in selected exploratory holes in January 2016. The monitoring results up to February 2016 show that groundwater beneath the study area ranges from 0.5m and 16.5m in depth. The results also show fluctuations in groundwater level with an overall maximum rise of 5.7m in BH14 (Lowestoft Formation) between 1st December 2015 and 17th February 2016.

Soil Infiltration Tests were carried out in accordance with BRE Digest 365 (2007), 'Soakaway Design' at four trial pits all located close to the proposed motorway junction and slip road. The results of these tests are summarised in Table 2.2 below.

Table 2.2: Study area soakage testing

Trial Pit ID	Ground Level (m AOD)	Hole Depth (m bgl)	Strata	Soil Infiltration Rate, f (m/sec)
TP 5	51.5	2.0	Lowestoft Formation / Glaciofluvial Deposits	Zero infiltration, test abandoned
TP 6	49.8	2.0	Head Deposits / Lowestoft Formation	7.028E-07
TP 7	50.8	2.0	Lowestoft Formation / Glaciofluvial Deposits	3.007E-05
TP 7	50.8	2.0	Lowestoft Formation / Glaciofluvial Deposits	2.918E-05
TP 8	52.4	2.0	Head Deposits / Lowestoft Formation	Zero infiltration, test abandoned

Based on a comparison with infiltration coefficients in Table 25.1 of the CIRIA SuDS Manual, the soakage results at TP7 indicate good infiltration media. The results at TP6 indicate poor infiltration media.

It should be noted that BRE 365 states that for an accurate infiltration rate to be obtained a soakage pit needs to be filled three times in quick succession. Each test is completed once 75% of the water present has drained away, in order to determine whether or not the underlying ground conditions may be suitable for surface water drainage. Only a single test was conducted in each trial hole due to time constraints on site, with the exception of TP7 in which two tests were carried out. TP6 was left open overnight, with data from 1380 minutes extrapolated in order to calculate an infiltration rate.

2.8 Existing abstractions

Based on a review of Envirocheck data and information provided by the EA, there is one groundwater abstraction Consent located within the study area (a second is listed as 'revoked'). The abstraction is within close proximity of the scheme (located near the proposed Sheering Road Roundabout) and the nearest trial pit is TP7. The abstraction is recorded as spray irrigation related to agricultural practices.

2.9 Existing drainage

It is believed that surface water runoff from the M11 currently drains via highway drainage to the Pincey Brook via an outfall, understood to be approx. 375mm in diameter, located immediately downstream of the M11 Pincey Brook culvert. Similarly, it is believed that runoff from Gilden Way currently drains via highway drainage to the Harlowbury Brook via outfalls (one on each bank) on the downstream side of Gilden Way Bridge. It is understood that the outfalls on the west and east side of the Harlowbury Brook are approx. 375mm and 600mm in diameter respectively. ECC's engineering team have advised that they do not hold drainage asset plans and are therefore unable to confirm existing drainage arrangements.

Surface water runoff from 'greenfield' land (in the location of the proposed link road) follows the natural topographic gradients and drains uncontrolled to the Pincey Brook and/or the un-named watercourse. Drainage to the un-named watercourse is then conveyed by twin 300mm diameter pipe(s) to an outfall into the Pincey Brook. There are no known controls on this outfall.

Thames Water Utilities Ltd is the local waste water services provider in the study area. Thames Water's Asset Location Plans (contained within Appendix B) shows that properties in the vicinity of Gilden Way are served by separate foul and surface water networks. The network is largely gravity-fed; however, there is a rising main in Gilden Way. The following sewers are indicated as being located within Gilden Way corridor.

- A 315mm diameter foul rising main in Gilden Way, running from a pumping station (east of Mulberry Gardens) to the west beneath the Harlow-bound carriageway. The rising main upsizes to a 450mm diameter pipe at a dog leg prior to London Road Roundabout before continuing to the north;
- To the south of Playground / Norman Booth Recreation Centre a 375mm diameter surface water sewer crosses Gilden Way from north to south. There is no levels data available;
- A 300mm diameter foul sewer crosses Gilden Way from south to north at Gilden Close. There is no levels data available; and
- A 150mm diameter foul sewer starts in Sheering Road at The Campions and runs to the south, continuing down Sheering Road rather than Gilden Road.

Asset Location Plans were only obtained for the urban area of Harlow, including Gilden Way, and a section of Sheering Road between The Campions and Gilden Way. The remainder of the study area is largely rural and is assumed to drain to local watercourses or private sewers. Based on the information and investigations summarised in Section 2.6, the geological characteristics of the scheme area would suggest the likelihood of drainage of surface water via soakaways to be low.

3. National Planning Policy Review

The aim of this section of the report is to discuss the main aspects of the local and national planning policies that are relevant to any proposed development on the site.

3.1 National Planning Policy Framework

The National Planning Policy Framework (NPPF) was published by the Department for Communities and Local Government (DCLG) in March 2012 and sets out the government's policies for planning in England.

The principal aim of the NPPF assessment of flood risk is that:

> *"Inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk but where development is necessary making it safe without increasing flood risk elsewhere."*

The NPPF requires a FRA to consider all potential sources of flooding to determine:

- the flood risk to the proposed development site; and
- the potential impact of the proposed development on flood risk elsewhere.

The NPPF technical guidance was withdrawn from use in March 2014 and replaced with The Planning Practice Guidance. The Planning Practice Guidance is a web based resource that was launched by the Department for Communities and Local Government (DCLG March, 2014) to support the NPPF. As an online resource it is therefore subject to change.

3.2 Assessment of flood risk

The main source of flood risk information that is used to steer development, at the Planning stage, is the EA's National Fluvial and Coastal Flood Map, known as the Flood Map for Planning (Rivers and Sea). This map is divided into three Flood Zones, with one Flood Zone subdivided into a further two. The Flood Zones are defined on a 'worst case' basis, ignoring the presence of existing defences. Table 3.1 (reproduced from Table 1 of the Planning Practice Guidance) shows the different classifications of Flood Zone and the probability of flooding associated with each Flood Zone.

As part of the FRA, the NPPF requires that developers consider not just the flood risk to the development but also the impact that the proposed development might have on flood risk elsewhere. As well as Main Rivers and the Sea, it is also necessary to consider flood risk from all other sources, including surface water, groundwater, Ordinary Watercourses, and artificial drainage systems and infrastructure failure.

Table 3.1: Flood Zone classification

Flood Zone	Description
Flood Zone 1 Low Probability	Land having a less than 1 in 1,000 (0.1% AEP[2]) annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map – all land outside Zones 2 and 3)
Flood Zone 2	Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding;

[2] Annual Exceedance Probability (AEP) refers to the chance that a flood of a particular size is experienced or exceeded during any year. In this report, we use a probability value expressed as a percentage to quantify this. For example, a 50% AEP flood event equates to a 1 in 2 chance of the flood being experienced or exceeded in a year. Similarly, the 0.5% AEP event equates to a 1 in 200 chance of the flood being experienced or exceeded in a year. Return period – this form of referring to event rarity has and continues to be commonly used within extreme event studies. The 2-year event is the same as the 50% AEP event, and the 200-year event is the same as the 0.5%. It refers to an on average spacing between floods of that size; however, it is important to note that a low probability does not preclude the event happening in the following year.

Medium Probability	Or Land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding. (Land shown in light blue on the Flood Map)
Flood Zone 3a High Probability	Land having a 1 in 100 or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding. (Land shown in dark blue on the Flood Map)
Flood Zone 3b Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map)

The proposed scheme is greater than 1 hectare and is largely located within Flood Zone 1. However elements of the scheme are shown on current EA flood maps to potentially be within Flood Zone 2. Consequently a FRA is required. As part of the FRA for the scheme, modelling of the Pincey Brook and un-named watercourse have been carried out in order to further assess flood zone boundary designations, as detailed in Section 5.3.

3.3 Sequential Test

The NPPF requires a risk-based sequential approach to determine the suitability of land for development in flood risk areas, which should be applied at all stages of the planning process. The Sequential Test should be applied to demonstrate that there are no reasonably available sites in areas with a lower probability of flooding that would be appropriate to the type of development proposed.

The EA's Flood Zones are the starting point for the Sequential Test and refer to the probability of sea and river flooding. They are defined on a 'worst case' basis, ignoring the presence of existing defences. The overall aim of the Sequential Test is to steer new development to areas with the lowest probability of flooding.

Several variations have been considered for the proposed route. Numerous factors, including flood risk have been taken into account in reaching a preferred location for the various elements of the scheme. The development of this linear road infrastructure is almost entirely located within areas of low flood risk and could not be achieved without crossing the watercourses in the area. Therefore the Sequential Test is deemed to be passed.

3.4 Vulnerability classification

The proposed development is given a vulnerability classification. Based on Table 2 of the Planning Practice Guidance, the scheme is classed as 'Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk'. In accordance with the NPPF, as shown in Table 3.2 (reproduced from Table 3, and associated footnotes, of the Planning Practice Guidance), Essential Infrastructure is considered appropriate in Flood Zones 1 and 2.

Table 3.2: Vulnerability classification

Flood Zone	Flood Risk Vulnerability Classification				
	Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Flood Zone 1	✓	✓	✓	✓	✓
Flood Zone 2	✓	Exception Test required	✓	✓	✓
Flood Zone 3a †	Exception Test required	✗	Exception Test required	✓	✓

Flood Zone 3b *	Exception Test required	✗	✗	✗	✓

NB. This table does not show the application of the Sequential Test which should be applied first to guide development to Flood Zone 1, then Zone 2, and then Zone 3; nor does it reflect the need to avoid flood risk from sources other than Main Rivers and the sea.
† In Flood Zone 3a essential infrastructure should be designed and constructed to remain operational and safe in times of flood.
** In Flood Zone 3b essential infrastructure that has to be there and has passed the Exception Test, and water-compatible uses, should be designed and constructed to 1) remain operational and safe for users in times of flood; 2) result in no net loss of floodplain storage; and 3) not impede water flows and not increase flood risk elsewhere.*

Where the scheme is located in Flood Zones 1 and 2, it is considered to be appropriate based on its vulnerability classification. Where any parts of the scheme are located in Flood Zones 3a or 3b, it is subject to the Exception Test. It should be noted that parts of the currently published flood zone designation in the vicinity of the scheme are subject to further assessment, as detailed in Section 5.3.

3.5 Exception Test

The NPPF requires the Exception Test to be applied if the development of Essential Infrastructure falls within Flood Zone 3. In applying the Exception Test it is the responsibility of the scheme developer to provide evidence that the development provides wider sustainability benefits that outweigh the flood risk to the site (Element 1) and to show that the development is safe from flood risk and that it doesn't increase flood risk elsewhere (Element 2).

The first part of the Exception Test is deemed to be passed as according to the scheme objectives the proposed scheme will:

- improve accessibility to and from Harlow;
- reduce congestion primarily for the A414 corridor;
- ensure the proposed infrastructure is of the appropriate scale for the future traffic demands of the stated growth; and
- facilitate future housing developments around Harlow and employment growth to the east of Harlow.

4. Local Planning Policy and Plans

National planning policy is supplemented at a local or regional level by additional plans and policies set out in Unitary Development Plans, Local Development Frameworks and Supplementary Planning Documents.

Locally set flood risk policies relate to specific local issues, such as drainage requirements for development within critical drainage areas, restrictions on infill development or minimum threshold levels for properties within the floodplain. These policies may specify specific flood risk mitigation measures to be adopted in certain locations.

At a regional level, the proposed scheme is located within the administrative area of ECC. At a local district level, the scheme is located within the administrative areas of HDC and EFDC. The western extent of EFDC extends across the M11 to Moor Hall Road and northwards to the west of The Campions, encompassing Pincey Brook. The River Stort thereafter marks the east-west boundary. The remainder of the scheme area is located within HDC.

The policy documents considered of greatest relevance to flood risk and drainage are listed below in chronological order. The scheme proposals have been developed, and designs are being progressed, with these policies and aims in mind. A comprehensive list of policies is documented in Chapter 3 of the Environmental Statement (ES).

- Adopted Replacement Harlow Local Plan (2006);
- Emerging Strategy and Further Options for the Harlow Local Development Plan (2014);
- Epping Forest Combined Local Plan 1998 and 2006; and
- Epping Forest Emerging Local Plan Consultation (2012).

These policy documents are supported and informed by technical reports.

4.1 Adopted Replacement Harlow Local Plan

The Adopted Replacement Harlow Local Plan (the Local Plan) sets out the planning policies which are currently used by Harlow Council to determine planning applications and to guide development across the Harlow District. The policies in the Local Plan were due to 'expire' on 13 July 2009; however, the Council sought the Secretary of State's agreement to issue a direction to 'save' them and submitted a list recommending those policies it wished to save to Government Office for the East of England. The Secretary of State's Direction dated 12 May 2009 agreed that all the policies recommended by the Council be saved. These included the following policies relating to flood risk and drainage.

"CP12: Development that will be at risk of flooding, or will contribute to flood risk or has an adverse impact on the river corridor will be resisted."

"NE13: In considering applications for new development affecting the quality of the water environment the Council:

1. Will oppose any adverse effect on watercourses and their corridors, or on groundwater quality or levels;

2. Will require the protection, maintenance and where possible enhancement of the River Stort, ponds, watercourses and field meadows;

3. May require the reinstatement and management of ponds;

4. May require the creation of new water areas, and the inclusion of schemes to enhance biodiversity;

5. All management schemes, including funding, must be agreed with the Council."

4.2 Emerging Strategy and Further Options for the Harlow Local Development Plan

The Harlow Local Development Plan will replace the Adopted Replacement Harlow Local Plan and will set out the framework to guide and shape development in Harlow to 2031 and beyond. Harlow Council ran a consultation on the Emerging Strategy and Further Options for the new Harlow Local Development Plan, having previously consulted on Issues and Options. Submission to Planning Inspectorate for Examination is anticipated in Spring 2017, with Expected Adoption and Publications in Summer 2017.

4.3 Epping Forest Combined Local Plan 1998 and 2006

At present this Council has a mixture of saved policies from the Adopted 1998 Local Plan and the Adopted 2006 Local Plan Alterations, in force. The policies are in line with NPPF and have been considered during the development of the scheme paying particular attention to policies U2a, *U2B, U3A and U3B.*

4.4 Epping Forest Emerging Local Plan Consultation

This Council has started the preparation of a new Local Plan which will replace the existing 1998 Local Plan and 2006 Alterations documents. The new Local Plan will guide development in the district up to 2033, being used to assess planning applications and to provide land allocations. Pre-submission publication and representations on soundness are scheduled during June/July 2017, with an expected adoption and publication (including policies maps) in October 2018.

5. Assessment of Flood Risk to the Proposed Development

The NPPF requires a FRA to be undertaken and the assessment must consider all potential sources of flooding to determine:

- The flood risk to the proposed development site; and
- The potential impact of the proposed development on flood risk elsewhere.

This section presents the assessment of all potential sources of flood risk to the proposed development.

5.1 Flood risk to the proposed development

In accordance with the NPPF, sources of flood risk considered include the following:

- Tidal – flooding from the sea and tidal watercourses;
- Fluvial – flooding from Main Rivers and Ordinary Watercourses;
- Surface Water – flooding from run-off and overland flow as a result of rainfall events;
- Groundwater – flooding due to the rising of the water table below ground;
- Reservoirs – flooding due to the overtopping or breaching of reservoirs;
- Canals – flooding due to overtopping or failure of canals; and
- Sewers – flooding that occurs as a direct result of surcharge of sewers or drainage assets.

5.2 Flood risk from the sea

The proposed scheme does not cross nor is located in close proximity to any tidal or tidally influenced watercourses, and is over 30km from the coast. The proposal is therefore not at risk from the sea or tidal watercourses.

5.3 Flood risk from Main Rivers and Ordinary Watercourses

Fluvial flooding typically occurs when the flow capacity of a river channel is exceeded and floodwater spills out of the banks into a floodplain. It can also happen when the downstream receiving watercourse has a high water level limiting the discharge of a tributary, which then overtops its banks and causes localised flooding. Fluvial flood problems are exacerbated when the natural floodplain is encroached upon or confined in any way. Flooding can also occur when culverts and bridges are blocked by debris or when the capacities of channels are reduced.

5.3.1 Main Rivers

The Environment Agency Flood Map for Planning (Rivers and Sea) mapping shows that the majority of the proposed scheme traverses through Flood Zone 1. Therefore, the flood risk to the majority of the proposed development is considered to be **low**. There are two areas of the scheme which potentially intercept Flood Zones 2 and 3 which are the floodplains of Harlowbury Brook to the south and Pincey Brook to the north of the scheme and may therefore be initially considered to be at **medium** to **high** risk. (Refer to Figure 2)

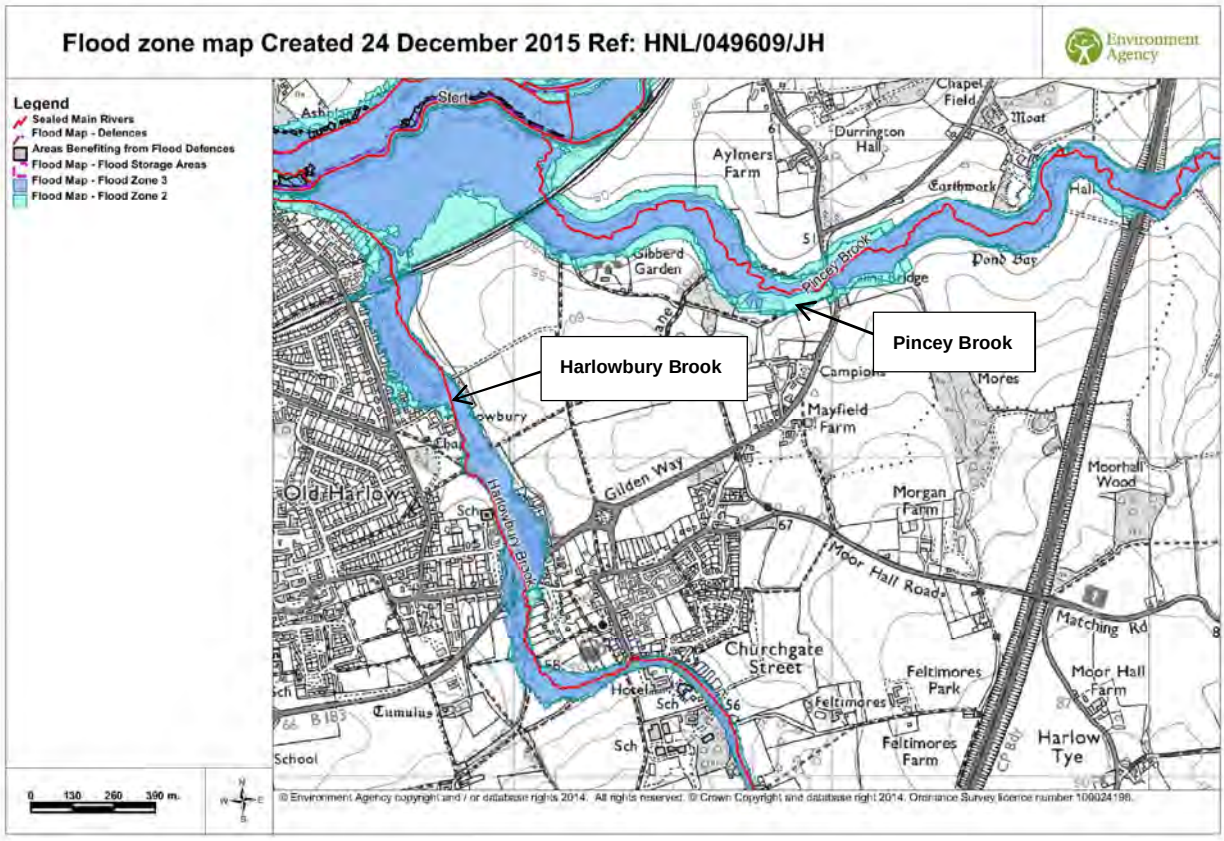

Figure 2: Environment Agency Flood Map (for scheme area)

5.3.1.1 Harlowbury Brook

The EA's Flood Map (Fig.2) indicates that the Gilden Way Bridge that crosses Harlowbury Brook is located within the floodplain. Historic flood incidents mapping within the HDC/EFDC SFRA, indicates that a flood incident at Gilden Way Bridge in 1978 affected a small area of land immediately upstream of the bridge. There are no known instances of historical flooding of residential properties in the vicinity of the bridge. It is likely that any fluvial flooding of Gilden Way would have also resulted in property flooding due to similarities in levels. In instances the road level is higher than that of the adjacent properties. ECC confirmed no recorded flood incidents.

In January 2011 WSP produced a FRA in support of a planning application for residential development of land to the north of Gilden Way (Planning Application Number HW/PL/15/00007). As part of the WSP FRA, consultation with the EA confirmed that the EA Flood Map is an indicative map and is not based on calculated modelled data. WSP therefore undertook 1D hydraulic modelling (InfoWorks RS v6.53) of the Harlowbury Brook to more accurately establish the 1% AEP flood extent, including a 20% allowance for climate change, and to predict peak flood levels. The modelled area comprised the section of the Harlowbury Brook immediately upstream of Gilden Way Bridge to the upstream side of the railway crossing to the north. A full topographical survey was used, including channel cross sections for Harlowbury Brook. Flood Estimation Handbook (FEH) catchment characteristics and the FEH Rainfall Runoff Method for Q100 were used. For catchments of this type, the Rainfall Runoff Method has been found to consistently over-estimate Q100 flows and, therefore, it was considered to be a conservative estimate for an in-flow boundary condition. The model does not extend further upstream of Gilden Way Bridge, therefore does not indicate whether areas upstream of the bridge are at risk of flooding. For the purpose of this outline assessment, however, the WSP hydraulic model results are considered to be a valid indication of flood risk.

The WSP model indicates that the floodplain extent both immediately upstream and downstream of Gilden Way Bridge is significantly less than that indicated by the EA Flood Map. The 1% AEP flood extent plus 20% climate change predicted peak flood level upstream of the bridge is 49.313m AOD, with the downstream level being

49.055m AOD. As outlined in Section 2.4, the existing level on Gilden Way at the bridge crossing is approximately 50.46m AOD. This infers that existing highway levels at the crossing point are at least 1.4m above the predicted peak flood level during the 1% AEP plus climate change flood event. Therefore, the impact of fluvial flood risk from Harlowbury Brook to the proposed scheme is considered **low**.

5.3.1.2 Pincey Brook

The 1% AEP flood extent of the Pincey Brook on EA flood maps is shown to encompass the M11, despite the culvert headwall of both the inlet and outlet being approximately 10m lower than the motorway level. Consequently, it is very unlikely that the M11 will experience flooding at this location. This suggests that the EA Flood Map is an indicative map and not based on calculated modelled data. Between the M11 and B183 the Pincey Brook flows through rural agricultural land and therefore there are very few flood receptors. Housing and out-buildings of Sheering Hall are shown to be at risk from the 0.1% AEP flood event. Where the Pincey Brook passes under Ealing Bridge on Sheering Road there is shown to be a risk of flooding up to the 0.1% AEP flood event.

Historic flood incidents mapping within the HDC & EFDC SFRA, confirms areas within the floodplain of the Pincey Brook including Ealing Bridge experienced flooding in 1947, 1978 and 2000. Details are unknown. Recent correspondence with ECC and EFDC has confirmed that ECC and EFDC hold no records of local fluvial flooding.

An existing hydraulic model received from the EA targeted the River Stort, and included the downstream section of the Pincey Brook. The included section does not extend far enough upstream to cover the development area of this scheme, and the Pincey Brook section of the model was not detailed enough for the FRA requirements.

A 1D 2D hydraulic model was therefore constructed using Flood Modeller (1D) and Tuflow (2D) and run as dynamically link 1D/2D flood model. (For full details of the model build and the verification process please refer to M11 Junction 7A Hydraulic Modelling Report in Appendix E.)

The upstream model boundary is upstream of the M11 crossing and the downstream boundary the railway crossing in the River Stort floodplain. The modelling also includes a 400m reach of the un-named tributary of the Pincey Brook (from The Mores) upstream from the outfall. The watercourse further upstream within the wooded area could not be accessed due to overgrowth and ponding therefore its characteristics are unknown.

The Baseline model was run for seven AEP events between the 50% and 0.1% AEP. In addition the baseline model was validated against water level records from the Gauge station 38026 at Sheering Hall. Four recorded flooded events were modelled dating back to 2011. The results showed a satisfactory level of calibration was achieved across the four calibration/verification events with both observed and modelled tail and head water levels within +/- 125 mm of each other. The model showed that flooding in the early part of the storm is caused by the flow constrictions at a number of river crossing structures most notably the railway line culvert and B183 road bridge. Capacity of the railway culvert is exceeded during a 50% AEP event and consequently significant ponding of flood water is predicted upstream of the railway line. Further upstream, the B183 road bridge also acts as a significant flow constriction and water is predicted to pond upstream of the road embankment. Neither embankment is predicted to be overtopped during a 1% AEP event but the B183 road embankment is predicted to be overtopped during a 0.1% AEP event.

With the exception of the areas upstream of the B183 road and Railway crossing, floodplain flood depth are less than 1 m and velocities in the floodplain are generally less than 0.5m/s.

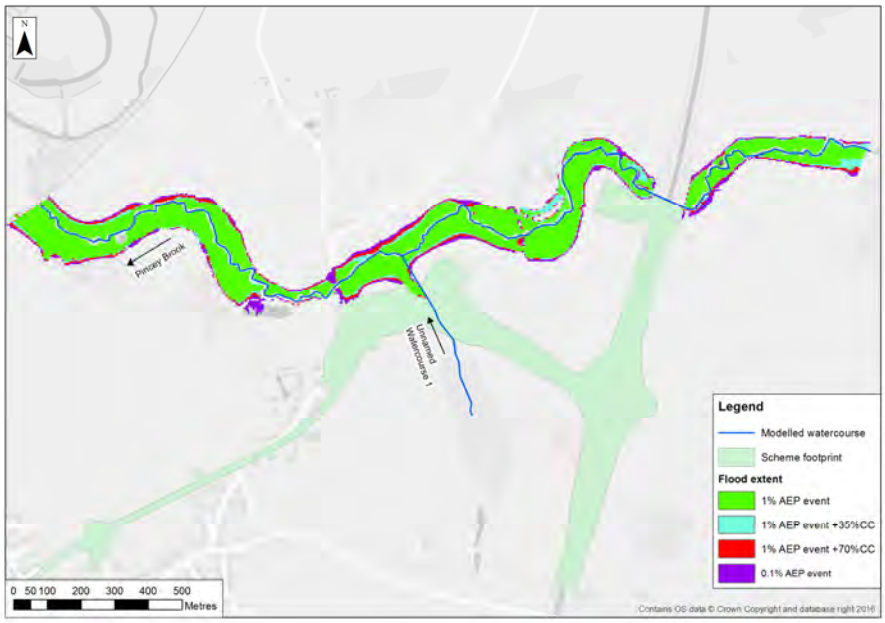

Figure 3: 1%, 1% CC (+35% and +70%), 0.1% AEP maximum flood extents predicted by the hydraulic model

Figure 4: Modelled 1% AEP flood extent and Environment Agency Flood Zone 3

The baseline model results are shown in Figure 3. Figure 4 shows the comparison of the modelled flood outlines with the existing EA flood map. The modelled extent indicates that the M11 and proposed new junction are located outside of the floodplain. The proposed link road also avoids the floodplain. Sheering Hall is located on the boundary of the extent of the 0.1 AEP flood. The modelling confirms that Ealing Bridge is at risk of flooding up to the 0.1% AEP flood event. Therefore, the impact of fluvial flood risk from Pincey Brook to the proposed scheme is considered **low**. Where the proposed development intersects with existing watercourses or drainage flow paths, there is potential for increased flood risk unless measures are incorporated to ensure continuity of flow route and capacity. This is discussed further in Section 6.2.

5.3.2 Ordinary Watercourses

The risk from the un-named tributary of Pincey Brook (from The Mores) is considered within the modelling undertaken and described above. There are no known instances of significant flooding of other un-named watercourses in the vicinity, other than anecdotal evidence of surface water ponding on local agricultural land. The proposed link road will be raised on embankments, which will further reduce the flood risk. Whilst the flood risk to the scheme from the un-named watercourse is considered to be low, it is important to consider how the watercourse will be conveyed through the embankments of the proposed link road, and this is considered in Sections 6 and 7.Flood risk from surface water

Surface water runoff is defined here as water flowing over the ground that has not yet entered a drainage channel or similar. It usually occurs as a result of an intense period of rainfall, which exceeds the infiltration capacity of the ground or the capacity of man-made drainage systems to convey flow. Typically, runoff occurs on sloping land or where the ground surface is relatively impermeable. The ground can be impermeable either naturally through the soil type or geology or due to development, which places large areas of impervious material over the ground surface (e.g. paving and roads).

According to the Harlow SWMP, Gilden Way Bridge is located in a Local Flood Risk Zone (LFRZ). A LFRZ is defined as a discrete area of flooding that does not exceed the national criteria for a 'Flood Risk Area' but still affects houses, businesses or infrastructure. Harlow SWMP also shows that a portion of the London Road Roundabout at the very south western end of Gilden Way is located on the corner of one of the areas delineated as a Critical Drainage Area (CDA) (No. 13). However, neither the 1% AEP surface water flood extent nor the EA Risk of Flooding from Surface Water map show any flood depths at this location.

Consultation with HDC has confirmed that there have been three recorded incidents of flooding in proximity to the scheme. These have been at No. 5 Gilden Close (to the southeast of Gilden Way Bridge), No. 38 Old Road (c.320m to the northwest of Gilden Way) and Churchgate Hotel on Churchgate Street (c.440m to the south of Churchgate Roundabout). HDC do not hold further details of these incidents. Based on the flow paths indicated on the EA Surface Water Map, it is likely that these incidents were associated with localised surface water flooding; however, this cannot be confirmed.

Using the Environment Agency's Updated Flood Map for Surface Water (uFMfSW), as shown in Figure 5, areas that are considered at risk from surface water flooding can be identified. There are three zones of risk for surface water flooding:

- High risk – an area that has a chance of flooding of greater than 1 in 30 (3.3%);
- Medium risk – an area that has a chance of flooding between 1 in 100 (1%) and 1 in 30 (3.3%); and
- Low risk – an area that has a chance of flooding between 1 in 1000 (0.1%) and 1 in 100 (1%).

Those areas at higher risk corroborate with topographic low points and local drainage routes and watercourses. The risk to the majority of the scheme is *Very low* to *low*. However there are discrete locations along the scheme which are indicated as *Medium* to *High* risk of surface water flooding. These surface water flow paths correlate with the existing topography and watercourses.

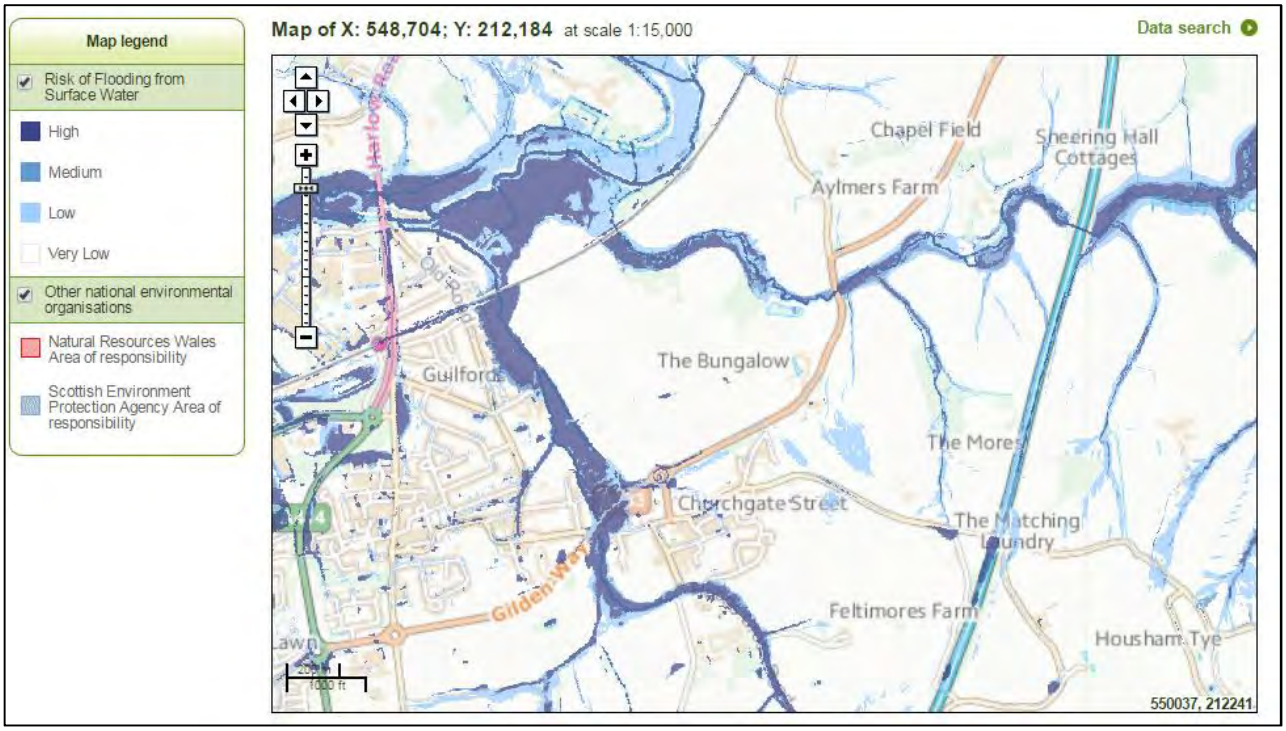

Figure 5: Environment Agency Risk of Flooding from Surface Water Map

The surface water flood risk associated with the Harlowbury Brook to the south appears to correlate with the fluvial flood extents shown within the EA Flood Map and is therefore assumed to reflect fluvial flooding. During flood events the Gilden Way Bridge may reach capacity and cause the Harlowbury Brook back-up. The flood risk is exacerbated by the inability of overland flow to discharge into the brook, particularly a flow path immediately to the southwest of the bridge. The EA map indicates that floodwaters spill into Gilden Close residential area on the south side of the road during a 3.3% AEP storm. Floodwaters then spill onto Gilden Way and over into The Oxleys residential area. The downstream risk between Gilden Way and the railway line is largely confined to the western bank and adjacent residential areas.

There are four overland flow paths draining into the Pincey Brook from the south, including the un-named tributary from The Mores. Two of these flow paths drain into the Pincey Brook at Sheering Hall. It does not appear that the residential property itself is at risk; however, it is important that flood risk at this location is not increased as a result of the scheme. Another flow path joins the Pincey Brook upstream of Ealing Bridge. The road is shown at *Very Low* risk, although land either side is at High risk. Further to the west, Gilden Way is largely at *Very Low* risk, with small isolated areas at *Low* risk. Churchgate Roundabout is shown as a *High Risk* location. This is likely to be a result of its low topographic level. The risk appears to be contained within the carriageway.

Based on the above, the risk of surface water flooding to the scheme is largely considered to be **low**; however, the four minor flow paths present a **moderate** risk to isolated areas. Mitigation measures are required to ensure that these flow paths are maintained and do not have a detrimental flood risk impact on the scheme. This is considered further in Section 7. In addition, residential properties on The Oxleys are located at a lower level than the road and, therefore, it is important to consider the potential impacts of the proposed road surface improvements on the surface water flood risk to these properties.

5.4 Flood risk from groundwater

Groundwater flooding occurs when the natural level of water stored within the ground rises above local ground level. This can result in deep and long-lasting flooding of low lying areas. It is most likely to occur in low-lying areas underlain by permeable rocks (aquifers).

Harlow SWMP 'Susceptibility to Groundwater Flooding Map with Reported Historic Incidents' indicates a variable susceptibility to groundwater flooding along the Gilden Way corridor. The level of risk indicated ranges from *Very Low* to *Very High***,** with the majority being at *High*. This includes Gilden Way either side of the Harlowbury Brook. The risk reduces to the west towards London Road Roundabout but increases to the east to Churchgate Roundabout. The areas of greatest risk generally correspond with the underlying Head and Lowestoft Formation Deposits. The map does not show any recorded incidents of groundwater flooding within the scheme area. There is no such map available for Epping Forest District.

HDC SWMP 'Infiltration SuDS Groundwater Protection Summary' map illustrates a *Low Susceptibility* to groundwater deterioration in the majority of the study area. The exceptions are Gilden Way Recreation Ground to the south of Churchgate Roundabout and two small areas to the west of Sheering Road in the vicinity of The Campions, where *Very Significant Constraints* are indicated. This is likely to be a result of being local topographic depressions with higher groundwater levels.

As outlined in Section 2.7, the ground investigation recorded groundwater within the Lowestoft Formation (1.2m to 19m bgl), Glaciofluvial Deposits (1.1m to 22.5m bgl) and London Clay Formation (24m bgl) between October 2015 and December 2015. Subsequent monitoring up to February 2016 encountered groundwater as shallow as 0.5m in depth, with fluctuations up to a maximum of 5.7m (BH14) within the Lowestoft Formation.

The proposed link road and Gilden Way are located over superficial deposits largely comprising the Lowestoft Formation. There is therefore potential for rising shallow groundwater to break the surface following prolonged rainfall. The likelihood of this affecting the proposed scheme is low given that BH14 is located in the vicinity of the proposed link road, which is to be raised above the existing ground level

The scheme, other than Gilden Way, is primarily located on top of London Clay, a sedimentary bedrock layer with generally a low permeability. Groundwater sampling confirms that groundwater within the London Clay is at 24m bgl. Consultation with the EA (contained within Appendix A) stated that the layer of London Clay underlying the scheme isolates the groundwater stored in the Chalk aquifer below and therefore there is minimal risk of rising groundwater from bedrock strata.

Based on the above, the risk of groundwater flooding to the junction and link road is considered to be **low**. Despite known shallow groundwater within the Lowestoft Formation in this area, the proposed link road will be raised on embankments. The risk to Gilden Way is considered to be **moderate** due to potential shallow groundwater at Gilden Way Recreation Ground. Mitigation measures are considered in Section 8.

There is currently limited research which specifically considers the impact of climate change on groundwater flooding. The mechanisms of flooding from aquifers are unlikely to be affected by climate change. If, however, winter rainfall becomes more frequent and heavier, groundwater levels may increase. Higher winter recharge, however, may be balanced by lower recharge during the predicted hotter and drier summers.

5.5 Flood risk from sewers

Flooding from sewers occurs when the sewer is overwhelmed by heavy rainfall, and incoming flow exceeds discharge capacity, or becomes blocked. As a result water can begin to surcharge the sewer network emerging at ground level through manholes and potentially causing flooding to highways and properties. If this occurs flooding could represent a significant risk to human health due to contaminants suspended in sewer flood water.

HDC SWMP 'Historical Flooding Overview' indicates 11 sewer flood records in an area of northeast Harlow District. This area comprises the scheme within Harlow District, Old Harlow to the north of Gilden Way and Churchgate Street to the south of Gilden Way. The northern extent of an area within the southeast of the district extends to the western section of Gilden Way prior to London Road Roundabout. This area has experienced 16 sewer flood records; however, the majority of these are likely to be within an urban area to the south beyond the scheme area. There are no details associated with any of these records.

According to the Sewer Flooding History Report provided by Thames Water (contained within Appendix B) there have been no incidents of flooding in the requested area as a result of surcharging public sewers. On this basis the risk to the scheme from sewer flooding is considered to be **low**.

There are also known to be existing high pressure water mains in the vicinity of the intended works. These however are considered to represent more of a risk during the construction phase, as discussed in Section 6.5.

5.6 Flood risk from reservoirs

There has been no loss of life in the UK from reservoir flooding since 1925. All large reservoirs must be inspected and supervised by Reservoir Panel Engineers. As the enforcement authority for the Reservoirs Act 1975 in England, the Environment Agency ensures that reservoirs are inspected regularly and essential safety work is carried out.

However, in the unlikely event that a reservoir dam failed, a large volume of water would escape and significant flooding could happen with little or no warning. Reservoir failure can be extremely dangerous due to the volume of water released in a sudden event. This can lead to the damage of property but more importantly presents a serious risk to life. However due to the measures in place under the Reservoirs Act 1975 the likelihood of a failure is remote. The EA's Risk of Flooding from Reservoirs Map indicates that there are four reservoirs within 10km of the proposed development which would affect the Pincey Brook in the unlikely event of a release of water. The four reservoirs are listed in Table 5.1.

Table 5.1: Reservoirs that cause inundation zone within study area

Name	Grid Reference	Owner	Area	EA Risk Designation
Hatfield Forest Lake	554187, 219751	The National Trust	EA – Hertfordshire and North London	To be determined
Shrubbs Farm Reservoir (ID395)	551864, 213504	Liddell	EA – Hertfordshire and North London	Not high risk
Balancing Pond C	554966, 221427	Stanstead Airport Ltd	EA – Hertfordshire and North London	To be determined
Kingstons Reservoir	555577, 212874	McGowan	EA – Hertfordshire and North London	To be determined

The Risk of Flooding from Reservoirs Map is shown as Figure 6. The flood risk areas associated with these reservoirs largely relates to the floodplain shown on the EA's Flood Map.

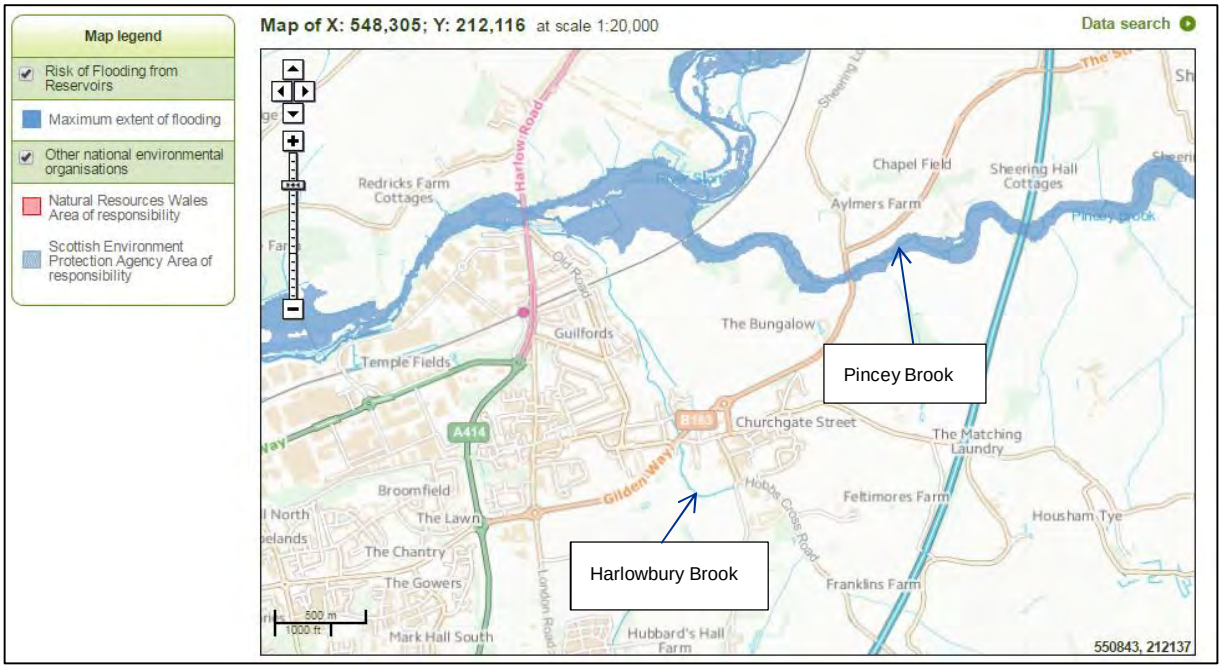

Figure 6: Environment Agency Risk of Flooding from Reservoirs

The risk of reservoir flooding affecting the proposed scheme is considered **low**.

5.7 Flood risk from canals

There are no canals in the study area.

5.8 Summary of flood risks to the proposed development

Table 5.2 summarises the results of the assessment of flood risks to the proposed site.

Table 5.2: Summary of flood risks to the proposed development

Source of flooding		Risk Assessment	Mitigation Required
Sea		Not Applicable	
Fluvial	Main River	Low	None
	Ordinary Watercourse	Low	None
Surface water		Low to moderate	Yes
Groundwater		Low to moderate	Yes
Sewers		Low	None
Reservoir		Low	None
Canal		Not Applicable	

6. The Impact of the Proposed Development on Flood Risk

This section of the report assesses the potential impact of the development of the proposed scheme and the effect it may have on the risk of flooding elsewhere.

6.1 Impact on flooding from the sea

As discussed in Section 5.2 the scheme is not in an area at risk of tidal flooding therefore no impact assessment is required.

6.2 Impact on fluvial flood risk

The majority of the proposed scheme and associated drainage is located outside of the floodplains of Harlowbury Brook and Pincey Brook (including the un-named watercourse from The Mores). However, as discussed previously there are two intersections with these watercourses.

There are no proposed works to the Gilden Way Bridge structure, and all proposed highway works will take place within the existing highway corridor. The widening of the existing carriageway and the addition of highway surfacing materials will therefore not affect fluvial flooding mechanisms or floodplain storage.

As discussed in section 5.3.1.2 the proposed link road, M11 junction and associated drainage are located outside of the modelled 1% AEP plus 70% climate change allowance floodplain of the Pincey Brook. The modelled hydrology is relatively unchanged as any additional runoff associated with the scheme is being attenuated and discharge is restricted (refer to section 6.3) and as such there is no significant change to the baseline hydrology. In addition the scheme requires no changes to Pincey Brook channel structures and with the exception of a slight increase in the embankment width at the B183 crossing there is no development within the modelled floodplain. Consequently there is no adverse effect of the scheme in the results of either the 1D or 2D modelling.

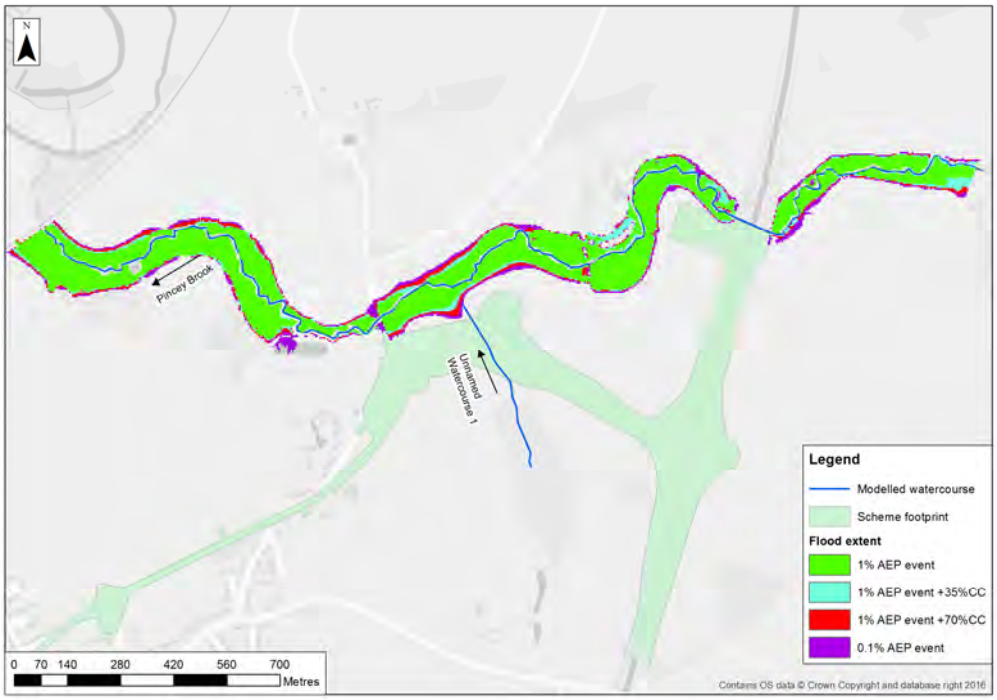

Figure 7: With Scheme 1%, 1% CC (+35% and +70%), 0.1% AEP flood extents

Where the proposed link road intersects the un-named watercourse (from The Mores) running towards the Pincey Brook a number of design considerations have been taken into account in order to mitigate any potential for increase in flood risk.

The downstream end of the un-named Ordinary Watercourse (from The Mores) will be re-routed slightly to the east of the existing open channel length that currently discharges to Pincey Brook via twin 300mm diameter pipes, thereby rendering the twin pipes redundant. The re-routed section will include two large area culverts under the proposed road embankments that have been included in the watercourse modelling carried out for Pincey Brook the results of which are summarised in Table 6.1 below.

Consideration of LLFA preferences and requirements has resulted in the selection of culverts of sufficient dimension to accommodate high flows and reduce the likelihood of blockage despite the presence of the woodland upstream (The Mores), as well as to allow safe access for inspection and maintenance. In addition, the proposed size of the two new culverts will enable the invert to be designed to suit low flows and ecological preferences whilst meeting the criteria for mammal passage (including bats).

Table 6.1: Proposed culvert information

Culvert No.	Catchment Area (km^2)	0.1% AEP flows (m^3/s)	1% AEP flows (m^3/s)	1% AEP +CC flows (m^3/s)	Length of box sections (m)	Culvert size
1a (south)	0.7	0.588	0.253	0.342	54m	2m x 2m Box
1b (north)	0.7	0.588	0.253	0.342	21m	2m x 2m Box

The remainder of the watercourse, between the two culvert locations and downstream of the north culvert, will be open channel to facilitate biodiversity and more natural geomorphological conditions. The works to open up the twin pipes will largely take place within the floodplain of the Pincey Brook; however, there will be no adverse impact on flood risk. Should the water level exceed the bank height, water will flow overland to the Pincey Brook to the north. There are no significant flood receptors in the flow path. The open channel will also be appropriately positioned to avoid works occurring in close proximity to the route of an existing large diameter gas main that currently crosses beneath both Pincey Brook and the M11. The downstream length of open channel provides significant opportunity for ecological improvement when compared to the existing small (300mm) diameter piped outlets to the Pincey Brook.

Although not currently forming part of the intended works, any future alterations to the culvert for the Pincey Brook underneath the M11 motorway should be such as to not reduce the flow capacity of the system. Any extensions of the culvert should have the same or larger cross sectional flow area as that of the current culvert.

Based on the above, the impact of the scheme on the flood risk from Harlowbury Brook and the Pincey Brook is considered to be **low.** Given the mitigation measures in place through the drainage strategy, the risk to the un-named Ordinary Watercourses is also considered to be **low**.

6.3 Impact on surface water flood risk

The construction of a hardstanding road corridor for the proposed scheme development will increase the impermeable area within the catchment compared with the existing situation. This has the potential to increase the surface water runoff and hence surface water flood risk in the area. The preliminary drainage design for the scheme, however, indicates that the whole of the runoff from scheme hardstandings will be managed by separate systems which will, following appropriate attenuation, discharge direct to local watercourses. This is further discussed in Section 7.

Overland runoff, where intercepted by the scheme, will be diverted using toe ditches or cut-off drains (and/or via the re-routed un-named watercourse) so as to outfall to the same watercourses as at present.

With the implementation of the above measures, as further detailed in Section 7, the impact of the scheme on surface water flood risk is considered to be **low**.

6.4 Impact on groundwater flood risk

Construction works and permanent infrastructure could result in the localised displacement of shallow groundwater to other areas. This could potentially result in groundwater breaking the surface in low-lying areas beyond the extent of the scheme.

The localised impact on groundwater in the Churchgate Roundabout area of Gilden Way is considered to be moderate, due to the potential impact on shallow groundwater at Gilden Way Recreation Ground and the increased vulnerability during wet periods when groundwater levels may rise locally. However, the attenuation features proposed in the vicinity of the Churchgate Roundabout are of relatively small capacity and reviews of the topography within the Recreation Ground suggest that the areas of 'made ground' indicated in the geotechnical reporting, may have been used to raise the levels of the sports pitches.

Under both normal and more extreme circumstances groundwater seepage will be managed by road drainage and the other drainage features and methods proposed (see Section 7). Due to shallow and potentially rising groundwater, seepage into temporary excavations may be possible in some areas. Standard construction measures should be applied to avoid adverse impacts on construction activities or risk to groundwater quality from potential pollution sources as a result. Groundwater pumping may be required as a short term measure to mitigate this risk, especially if the excavation coincides with a sustained wet period. It is recommended that, where practical, excavation takes place during the drier months to reduce the risk of groundwater emergence.

With the implementation of the above approach and the measures further detailed in Section 7, the overall impact of the scheme on groundwater flood risk is considered to be **low**.

6.5 Impact on sewer flood risk

The scheme should not increase the risk of flooding from existing services. To this end the exact locations of the services (including high pressure water mains) need to be ascertained before any work commences on site to avoid pipe bursts during construction. The scheme will be designed to avoid creating areas where the runoff from services can collect and present a flood risk.

In general, existing highway drainage is to be upsized or abandoned and replaced where required to take the additional flows generated by the scheme. Therefore, this aspect of the scheme is likely to have a positive impact on the risk of sewer flooding as existing systems will upgraded to meet latest design guidance. The proposed drainage strategy is outlined in more detail in Section 7.

Overall the impact of the scheme on sewer flood risk is considered to be **low**.

6.6 Impact on reservoir flood risk

The inundation zone of the EA 'Risk of Flooding from Reservoir' map is associated only with Pincey Brook. The proposed scheme is outside this zone, therefore the impact of the scheme on flood risk from reservoirs is considered to be **low**.

6.7 Impact on canal flood risk

As confirmed in Section 5.8 the scheme is not in an area at risk of canal flooding therefore no impact assessment is required

6.8 Summary of flood risks

Table 6.2 summarises the results of the assessment of the potential impact of the scheme development on flood risk elsewhere. The assessments of risk assume the implementation of the identified mitigation measures.

Table 6.2: Summary of flood risks impacts from the proposed scheme

Source of flooding		Risk Assessment	Mitigation Required
Sea		None	None
Fluvial	Main River	Low	None
	Ordinary Watercourse	Low	See Section 6.2
Surface water		Low	See Section 7
Groundwater		Low	See Sections 6.4 & 7
Sewers		Low	None
Reservoir		Low	None
Canal		None	None

7. Surface Water Drainage Philosophy

The aim of this section is to outline an appropriate drainage strategy that will mitigate the risk of flooding as a result of the proposed increase in impermeable surfaces following development of the scheme.

7.1 Objectives

The objectives of the drainage strategy are as follows:

- Remove water from the carriageway;
- Mitigate the impact of increased impermeable area on receiving watercourses;
- Mitigate any increase in surface water flood risk; and
- Control road runoff prior to discharge.

7.2 Drainage options

The drainage hierarchy in the Building Regulations Part H requires that the first choice of surface water disposal should be to discharge to an adequate soakaway or infiltration system, where practicable. If this is not reasonably practicable then discharge should be to a watercourse. The least favoured option is discharge to sewer (and then surface water before combined).

7.2.1 Infiltration

The HDC SWMP Infiltration SuDS Suitability Map covers both the Harlow District and the parts of the scheme area within Epping Forest District. The map shows there are significant constraints to infiltration within the floodplains of Pincey Brook, its tributary and within the vicinity of the Gilden Way Recreational Grounds to the south of Churchgate Roundabout. It is also indicated on the HDC SWMP Infiltration SuDS Ground Stability Summary that the Pincey Brook floodplain has significant potential for geo-hazards. Opportunities for bespoke infiltration are shown, however, particularly to the south of the Pincey Brook and immediately west of the M11. There are also opportunities indicated in the vicinity of Gilden Way Bridge, although potentially shallow ground water in places may well negate these opportunities.

The extent of infiltration testing undertaken during the ground investigation is largely limited to the vicinity of the M11 and the proposed link road. The results indicate good infiltration within the Lowestoft Formation / Glaciofluvial Deposits and poor infiltration within the Head / Lowestoft Formation. Given the spatial limitation of the soakage testing and the variable (hence inconclusive) results, the use of infiltration drainage to discharge surface water runoff to superficial deposits cannot be determined. Furthermore, the scheme is underlain by a bedrock geology made up of the London Clay Formation. The highly impermeable characteristics of this layer tend to preclude the use of infiltration drainage.

Based on the above, and the identified contamination risk to existing aquifers, the use of infiltration drainage has been discounted from this assessment. This may be reviewed for particular areas during the later more detailed design stages with site-specific targeting of further soakage testing.

7.2.2 Watercourses

As per the existing arrangements for the M11, Gilden Way and ‘greenfield’ land (see Section 2.9) surface water will be drained to local receiving watercourses.

7.3 Highway Catchments

The proposed scheme will increase the area of impermeable surfaces compared to the existing situation. This has the potential to generate additional surface water runoff and thereby increase flood risk in the area during any given storm event. There are residential receptors at The Campions and Mayfield Farm, on either side of Gilden Way, which could be at risk without appropriate management of surface water.

In order to mitigate the impact of increased impermeable area on receiving watercourses, and to minimise flood risk, the rates of discharge of surface water to receiving watercourses will be controlled. The scheme has been broken down in to three main highway catchments;

- Catchment A -Gilden Way (south and north)
- Catchment B -Proposed Link Road (incl. Sheering Road Roundabout)
- Catchment C -M11 Junction 7A

The proposed scheme will broadly increase the area of impermeable surfaces compared to the existing situation as summarised in Table 7.1.

Table 7.1: Summary of flood risks to the proposed scheme

Highway Catchment	Approximate increase in impermeable area (ha)	Basis for proposed Discharge Rates (to be used in design), following discussions with ECC (as LLFA)
Proposed Junction 7A	2.2	A rate this is no more than 50% of the existing 1 in 1 year 'brownfield' (from existing contributing areas) discharge rate, in addition to the 1 in 1 year 'greenfield' runoff rate for the proposed additional highway catchment area.
Proposed Link Road (incl. Sheering Road Rdbt)	2.35	The 1 in 1 year 'greenfield' runoff rate from that catchment or 1 l/s*, whichever value is larger.
Gilden Way	1.2	The existing Gilden Way catchment is currently assumed to be served by two independent drainage systems, one to the north of Harlowbury Brook and another to the south. It is proposed to restrict the discharge of surface water from the two Gilden Way systems to the Harlowbury Brook to the lowest practically achievable rates.
TOTAL	5.75	

*The CIRIA SuDS Manual and EA guidance suggest a practical lower limit on the discharge rate from a flow attenuation device of 5 l/s, in order to attenuate to a satisfactory low flow rate whilst achieving an acceptable risk of blockage.

7.3.1 Methodology for calculating discharge rates

Using details of the existing networks, where available, the existing 'brownfield' (i.e. existing contributing areas) situations were modelled using Micro Drainage software, and then storm events of varying return period simulated through the networks to determine the flow rates at the outfalls.

The 1 in 1 year 'greenfield' runoff rate was estimated using a Flood Estimation Handbook (FEH) method. The median annual maximum flood (QMED) was estimated using a calibrated hydrological (Revitalised Flood Hydrograph (ReFH)) model for the relevant watercourse and its surface catchments along the hydraulic model reach (applied to the two hydrological sub-catchments that are proposed to feature ponds along the watercourse, selecting the lowest value of the two). The URBEXT value (which defines urban extent) in the ReFH unit was set to zero to represent the 'greenfield' condition. Flood Studies Report (FSR) statistics were then used to factor the QMED value to a 1 in 1 year 'greenfield' runoff rate. The result of the FEH method was compared with the value found using the traditional Institute of Hydrology Report 124 (IH 124) method.

7.4 Storage options

In order to restrict the discharge of surface water to watercourses to a controlled rate it will be necessary to provide appropriate attenuation. Three basic options are considered for the proposed scheme based on the feasibility of incorporating these features within the scheme parameters.

7.4.1 Attenuation ponds

Attenuation ponds are landscaped depressions that are designed to have a wet invert (0.5m of water below outlet level) under normal conditions, and designed to store water during and after storm events, and restrict the rate of outfall of water to the receiving watercourse. The ponds can be vegetated to provide water quality treatment.

Operation and maintenance requirements for ponds are highlighted within Part D of the CIRIA C753 SuDS Manual. Regular and occasional maintenance schedules are required to prevent ponds and banks becoming overgrown by vegetation. Remedial actions need to be developed in case of an emergency maintenance event such as eutrophication, erosion or direct damage. Pond conditions should be monitored at regular intervals. Any sediment excavated from the ponds may contain contaminants and should be tested prior to disposal to landfill (or if intended to be re-used elsewhere) under relevant waste management regulations.

7.4.2 Oversized pipes

Oversized pipes could be used to attenuate surface water runoff prior to discharge into the receiving watercourse(s). Using oversized pipes to provide attenuation (as an alternative to attenuation ponds) could reduce the width of the corridor required for the provision of surface water attenuation.

The use of oversized pipes requires key operation and maintenance considerations. The necessity to effectively maintain the road and drainage is driven by three core principles; safety, serviceability and sustainability. Although the pipes will be designed to achieve a minimum self-cleansing velocity, pipes should be intermittently checked for signs of deterioration.

7.4.3 Hybrid Scheme

In the event that a single option cannot be suitably incorporated into the design of the scheme, a hybrid option may be considered incorporating a combination of oversized pipes and ponds depending upon the sub-catchment being drained.

7.5 Proposed strategy

This drainage strategy is based on the above philosophy and has been developed with consideration to planning policy and current DMRB guidelines. In order to define the proposed scheme drainage solution, the use of SuDS for surface water management and disposal of surface water runoff and the guidance given in the CIRIA publication C753 (The SuDS Manual) has also been considered in this assessment.

7.5.1 Proposed Junction 7A

It is proposed to upgrade sections of the existing M11 drainage as part of its connection to the new drainage on the slip roads and junction. The existing system will need to be upsized to accommodate the additional runoff and to meet the latest design guidance. It is understood that the existing system currently discharges directly into Pincey Brook with no attenuation. As preferred by ECC (as LLFA), it is proposed to restrict the discharge to a rate that is no more than 50% of the existing 1 in 1 year ‘brownfield’ (from existing contributing areas) discharge rate, in addition to the 1 in 1 year ‘greenfield’ runoff rate for the proposed additional highway catchment area.

Runoff will therefore be drained to an online attenuation pond located adjacent to Pincey Brook to the west of the M11 and north of the proposed link road. Both the pond and the invert level of its outlet will be placed outside of the Pincey Brook 1% AEP (plus 70% climate change allowance) floodplain and therefore no

compensatory storage will be required. This has been the basis of early pre-application discussions in principle with ECC (as LLFA) and the EA.

The outfall from the pond will be co-ordinated with the existing M11 drainage system outfall to the Pincey Brook, which is currently understood to be a 375mm diameter pipe.

The proposed pond depth is approximately 2.5m, which includes for a 300mm freeboard and a permanent wet volume (based on a 500mm depth) below the outlet pipe will be planted to provide water quality enhancement. The pond will be lined in order to reduce the risk of contamination of the underlying aquifers.

Refinement of pond footprint areas will be influenced at the more detailed design stages by the localised topography at the pond positions, and the need to minimise environmental impacts resulting from the earthworks required.

7.5.2 Proposed link road

Preliminary drainage designs indicate that the proposed link road will be drained to a pond to the north of the proposed new Sheering Road Roundabout. The outfall from the pond can discharge direct to Pincey Brook or via the un-named watercourse, depending on the outcome of further water quality considerations during detailed design. Both the pond and the invert level of its outlet will be positioned outside of the Pincey Brook 1% AEP (plus 70% climate change allowance) floodplain and therefore no compensatory storage will be required. This has been the basis of discussions in principle with ECC (as LLFA) and EA.

The proposed pond depth is approximately 2.5m, which includes for a 300mm freeboard and a permanent wet volume (based on a 500mm depth) below the outlet pipe will be planted to provide water quality enhancement. The pond will be lined in order to reduce the risk of contamination of the underlying aquifers.

Runoff from the soft landscaped embankments of the link road will naturally gravitate downslope. Where water is expected to flow directly towards the Pincey Brook, no embankment toe drainage ditches or top of cutting cut-off drains are considered to be necessary. At two locations, to the north and south of the link road, landscaping and land re-profiling will be undertaken to remove steep slopes whilst maintaining direction of flow towards the un-named watercourse. In all other locations toe drainage ditches and cut-off drains are to be incorporated into the scheme. Where provided, toe ditches and cut-off drains will be connected to highway drainage or local watercourses as appropriate.

Refinement of pond footprint areas will be influenced at the more detailed design stages by the localised topography at the pond positions, and the need to minimise environmental impacts (including tree/hedge removal) resulting from the earthworks required.

7.5.3 Gilden Way

The current drainage assets are associated with two lanes of traffic and therefore assumed to have been sized and positioned accordingly. Given the proposed works to extend the width of the highway to provide an additional lane, it is proposed to abandon the greater part of the current drainage system and incorporate a new system specifically sized and positioned to suit the new carriageway layout.

As the proposed highway works are constrained to be within the existing highway corridor, the space readily available for drainage purposes is extremely limited. The need to co-ordinate the positioning of drainage infrastructure with existing and proposed utilities, and landscaping and noise mitigation works adds to the complexity of providing drainage systems along Gilden Way with a significant reduction in discharge rates when compared to the existing. Space constraints have been potentially eased in certain locations by the assumption that use of Harlow District Council (HDC) owned land may be considered for this part of the project.

The preferred attenuation SuDS features are ponds; however, there are few large enough open areas available in close proximity to the low points of Gilden Way. It is proposed to attenuate flow with ponds/tanks located part way along each system, with the remaining storage being provided by online oversized pipes positioned either under the new verge, footpath or road.

It is proposed to locate a pond for the Gilden Way north system in the Recreation Ground to the southeast of Churchgate Roundabout, adjacent to the existing sports pitches. The pond will be sympathetically located, designed and landscaped to mitigate groundwater risks and to limit the impact on the existing sports pitches, although it is likely that a large proportion of the existing mature trees at the western end of the area will need to be removed. At this point in the system, a small underground tank will also be introduced to attenuate flows from the adjacent roundabout and the existing road catchment to the south of the roundabout. The tank will be located to the southwest of Churchgate Roundabout on a parcel of HDC land that abuts the roundabout. The tank will be positioned in order to minimise tree disturbance, although some tree removal will be required.

The pond and tank adjacent to the Churchgate Roundabout are both of relatively small volume but will both be lined in order to avoid contamination of the underlying aquifers, and potential groundwater problems in extreme circumstances. The liners will be designed so as to accommodate external water pressures when water levels in the pond/tank are low. Where necessary, the highway drainage system will be designed to assist the management of groundwater seepage.

A similar approach is proposed for the Gilden Way south system with a pond located part way along the system on an area of land also under the ownership of HDC. The land abuts the existing highway corridor and is edged with trees. The pond will be sympathetically sized, located and detailed in order to minimise the impact on the existing trees.

Both Gilden Way systems (north and south) will discharge into the Harlowbury Brook. Measures aimed at water quality mitigations will include the incorporation of oil interceptors with silt traps, as appropriate.

7.6 Pollution control

DMRB guidance for spillage control specifies a number of potential options for the effective containment of spillages where required on the proposed highway and at junctions. These will be investigated at the detailed design stage and appropriate measures adopted accordingly.

Attenuation ponds will provide treatment of surface water prior to discharge into the receiving watercourses. They will potentially allow time for sediment and heavy pollutants to settle to the bottom of the pond before discharge. Planting in the wet base of the ponds will also be an aid to enhanced water quality. Prior to discharge into the receiving Harlowbury Brook watercourse, oil interceptors will be included within the Gilden Way drainage system to further minimise pollution effects.

7.7 Maintenance

Whilst a range of design measures have been incorporated into the development proposals, it is important that these continue to be effective during the life of the scheme. It is assumed that new assets will be incorporated within current inspection and maintenance programmes, and that the assets provided to mitigate flood risks will be regularly inspected and maintained.

It is assumed that the drainage assets on the M11 Junction 7A, including the attenuation pond, along with the bridge structures and slip roads will be managed and maintained by Highways England. Drainage within the Link Road and Gilden Way will be managed and maintained by ECC as the Highways Authority or as LLFA. Precise definition of maintenance roles, responsibilities and requirements will be confirmed at the detailed design stage.

8. Mitigation Measures and Residual Risks

This section outlines the mitigation measures required to reduce the impact of the proposed development on flood risk, as well as highlight the residual risks that remain once the mitigation measures have been incorporated.

8.1 Mitigation Measures

The design of the scheme includes a number of measures to mitigate the impact on flood risk. These include:

- The road drainage will restrict runoff from the scheme based on reduced existing discharge rates and/or greenfield runoff rates, and will provide attenuation for storm events up to and including the 1% AEP event, plus a 30% allowance for climate change;
- Embankment toe ditches and top of cutting cut-off drains along the upslope side of the link road will collect surface water runoff from the existing small surface water flow paths and residual rural catchment runoff (including from the embankment slope) and drain it to flow path crossings, e.g. to the un-named watercourse from The Mores.
- The culverts at the two crossings of the un-named watercourse from The Mores will be of a sufficiently large cross-sectional area to accommodate high flows and minimise the likelihood of blockage.
- The online attenuation ponds and tanks will be lined to prevent contamination of the underlying aquifers and ground water emergence. Liners will be designed to prevent ground water emergence when water levels within ponds and tanks are low. Drainage features and a localised re-profiling of ground levels will be designed to further mitigate groundwater related risks.

8.2 Residual Risks

A number of residual risks remain following development of the scheme including the incorporation of the mitigation measures. These are outlined in the below.

8.2.1 Breach of attenuation ponds

A breach of an attenuation pond could occur in two ways: structural failure of the side slopes/embankments or overtopping caused either by exceedance of the design water level or a blockage. The likelihood of failure or overtopping caused by exceedance of the design standard is very low given that the ponds will be positioned so as to minimise the extent of embankments required and have been designed to a 100 year standard plus a 30% climate change allowance. The residual risk in this respect is considered to be **low**.

There remains a risk of blockage. Regular maintenance, as per the adopted arrangements by ECC and Highways England will reduce the risk of blockage.

In the unlikely event of a breach there would be the potential for a short term increase in fluvial and surface water flooding.

8.2.2 Reservoir failure

As explained in Section 6.6, reservoir flooding is extremely unlikely to happen. There has been no loss of life in the UK from reservoir flooding since 1925. All large reservoirs must be inspected and supervised by Reservoir Panel Engineers. As the enforcement authority for the Reservoirs Act 1975 in England, EA ensure that reservoirs are inspected regularly and any essential safety work is carried out. In the unlikely event of failure, the zone of inundation, as shown on EA reservoir maps, would not affect the scheme. Therefore, the residual risk is considered to be **low**.

8.3 Environmental permitting and consents

As of the 6 April 2016, under the Environmental Permitting (England and Wales) (Amendment) (No. 2) Regulations 2016 (2016/475), an Environmental Permit may be required where a flood risk activity is undertaken in, over, under or adjacent (typically within 9m) to a Main River. The regulations set out an extensive range of flood risk activities including erection of structures in, over or under a Main River; works to structures that are likely to affect the flow of water or drainage work in respect of a main river; dredging activities; works on floodplains that are likely to divert or obstruct floodwaters; and activities in the vicinity of flood defences which are likely to cause damage, endanger stability or reduce effectiveness of those defences. Both temporary and permanent activities apply.

Whilst preliminary design work has aimed to minimise the extent of the works proposed within 9m of the two Main Rivers (by largely restricting such works to buried pipes and related outfalls, once the detailed nature of the works are known, consultation with the EA should be undertaken to confirm whether an Environmental Permit is required for the likes of the works in the vicinity of the Gilden Way Bridge that may affect the structure and/or Harlowbury Brook.

Works within 9m of an Ordinary Watercourse may also require consent from ECC as LLFA and this will be confirmed during the more detailed phases of the design.

9. Summary and Conclusions

The proposed scheme comprises the following elements:

- New grade separated junction consisting of an overbridge and roundabouts above the existing M11 motorway;
- New slip roads to the south and to the north of the new junction;
- Roundabouts connecting the motorway to the existing B183 Sheering Road/Gilden Way in the west;
- Re-routed and culverted section of un-named Ordinary Watercourse discharging to Pincey Brook
- Approximately 2km of improvement works along Gilden Way (B183), from the general area of Mayfield Farm to its junction with London Road Roundabout in the west.

Works on Gilden Way comprise widening of the existing carriageway to create an additional lane, and road surface improvement works. All carriageway works are within the highway corridor of the original Gilden Way. There are no proposed works to the Gilden Way Bridge over the Harlowbury Brook.

A FRA has been carried in accordance with NPPF as part of the Environmental Report that will accompany a Planning Application for the proposed road scheme. The development is classified as “Essential Infrastructure”, which is permitted in Flood Zones 1 and 2. Given the largely low risk and appropriate nature of the development the Sequential Test is deemed to be passed, however, the Exception Test must be passed in order for development to be permitted in Flood Zone 3a.

Numerous factors including flood risk have been taken into account in developing the proposed highway alignment. The alignment is largely situated in areas of low flood risk and the development of this linear road infrastructure could not be achieved without crossing an Ordinary Watercourse (two crossings of the un-named watercourse from The Mores) and a Main River (Harlowbury Brook).

Flood risks have been considered from a range of sources including rivers, surface water, groundwater, sewers and artificial drainage systems, canals, and reservoirs. Flood risk from all sources is considered low with the exceptions being from surface water and groundwater where the risk, without mitigation, is considered low to moderate. The EA Flood Map appears to identify significant risk of fluvial flooding where the scheme intersects with, or is in close proximity to existing watercourses. However, the flood mapping at these locations is accepted as being indicative and not based on calculated modelled data. Hydraulic modelling carried out for Pincey Brook and the un-named watercourse from The Mores, has provided a further assessment of flood zone boundaries in the vicinity of the M11 and Sheering Road Roundabout ponds. Similarly the reporting of previous modelling of Harlowbury Brook has been used to further assess risks at the Gilden Way Bridge location. These further assessments have confirmed the major elements of the scheme to be situated in areas of low flood risk.

The impact of the proposed development on flood risk elsewhere is considered low, provided that appropriate mitigation measures are adopted for surface water, groundwater and the two crossings of the un-named watercourse from The Mores.

The proposed development would introduce a substantial amount of impermeable road surface to the rural area which could increase flood risk. A Drainage Strategy for the scheme proposes to manage runoff by providing attenuation for events up to and including the 100 year storm plus a 30% allowance for climate change to restrict discharges based on reduced existing discharge rates and/or greenfield runoff rates. Discharge will be to surrounding surface watercourses. Overall the impact from surface water runoff will be low with the final level of ‘betterment’ subject to further consultation regarding constructability/practicality aspects of the works.

By adopting the mitigation measures outlined, the scheme will not be at significant risk of flooding from any source and will not increase the flood risk elsewhere. The proposed development is, therefore, compatible with existing flood risk and in accord with national and local policy and is considered acceptable.

10. References

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Appendix A. Environment Agency Consultation and Maps

Our ref: HNL/049609/JH

Your ref:
B1279873/REA/UTL/RAM/JC/EA2

Date: 24 December 2015

Dear James Cullinane

Enquiry regarding Re: Harlow Eastern Access Improvements, M11 Junction 7a Flood Risk Assessment

Thank you for your enquiry which was received on 26 November 2015.

We respond to requests under the Freedom of Information Act 2000 and Environmental Information Regulations 2004.

The area in which your proposed development is located sits on top of London Clay, a rock layer of very low permeability. This layer of London Clay isolates the groundwater stored in the Chalk below. The level of the groundwater table in the Chalk is therefore not relevant to the flood risk in this area. However, the low permeability of the London Clay means the area has poor drainage. This means that any water retained in this layer or the soil above it may accumulate in low-lying areas and cause flooding. Following the Flood and Water Management Act 2010, Lead Local Flood Authorities are now responsible for the management of groundwater and surface water flooding. They also maintain a register of property flooding incidents. You may want to seek further advice Essex County Council, the LLFA in your area.

Aquifer maps can be viewed online at http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=groundwater.

I have attached a ground water contour map for groundwater levels.

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The depth to groundwater map shows the distance measured from the ground level to the top of the water in the borehole in the chalk aquifer. It is recorded as metres below ground level.

FLOODS DESTROY BE PREPARED

The site in question falls does not fall within a groundwater Source Protection Zone (SPZ). These zones show the risk of contamination to a public water supply from any activities that might cause pollution in the area. The closer the activity, the greater the risk. We use the zones in conjunction with our Groundwater Protection Policy to set up pollution prevention measures in areas which are at a higher risk. They also help us to monitor the activities of potential polluters nearby.

You can view our Source Protection Zone maps on our 'What's in your backyard' pages at http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=groundwater

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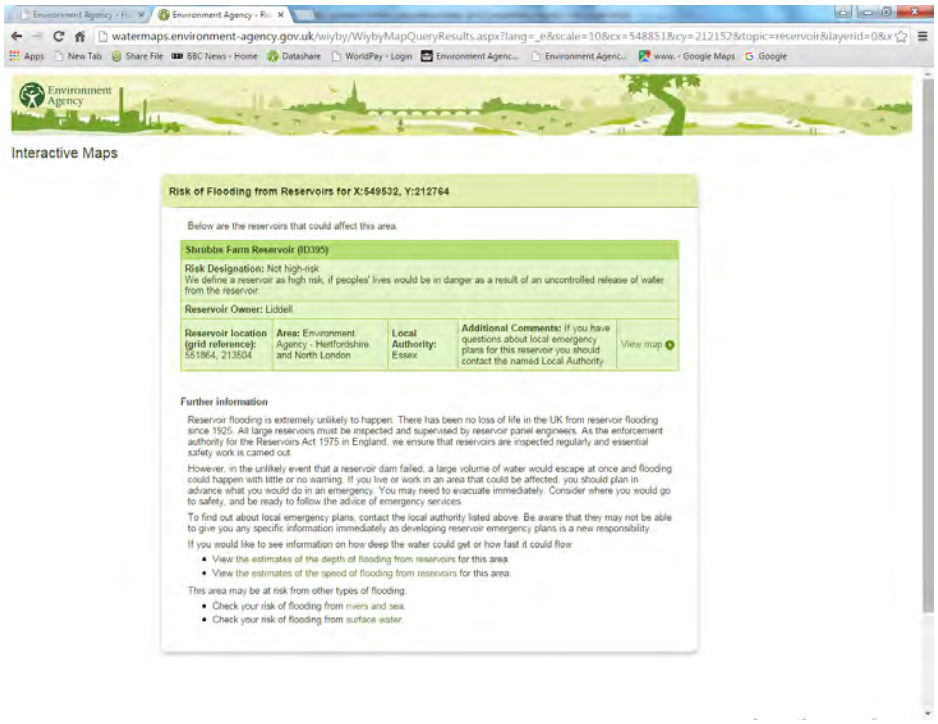
In your area, the Flood Zones are formed of generalised national modelling which was used in 2004 to create fluvial floodplain maps on a national scale. In some areas the Flood Zones are not aligned with the watercourse, this is because we have not carried out a detailed local assessment of flood risk.

Details on reservoir flooding area available from our web site via this link: http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?lang=_e&topic=reservoir&layer=0&x=548851&y=212152&scale=10&location=CM17+0JP#x=548851&y=212152&scale=10

Below are the details associate to your area of interest.



Interactive Maps

Risk of Flooding from Reservoirs for X:549532, Y:212764

Below are the reservoirs that could affect this area.

Shrubbs Farm Reservoir (ID395)

Risk Designation: Not high-risk
We define a reservoir as high risk, if peoples' lives would be in danger as a result of an uncontrolled release of water from the reservoir.

Reservoir Owner: Liddell

Reservoir location (grid reference):	Area:	Local Authority:	Additional Comments:	
551864, 213604	Environment Agency - Hertfordshire and North London	Essex	If you have questions about local emergency plans for this reservoir you should contact the named Local Authority	View map

Further information

Reservoir flooding is extremely unlikely to happen. There has been no loss of life in the UK from reservoir flooding since 1925. All large reservoirs must be inspected and supervised by reservoir panel engineers. As the enforcement authority for the Reservoirs Act 1975 in England, we ensure that reservoirs are inspected regularly and essential safety work is carried out.

However, in the unlikely event that a reservoir dam failed, a large volume of water would escape at once and flooding could happen with little or no warning. If you live or work in an area that could be affected, you should plan in advance what you would do in an emergency. You may need to evacuate immediately. Consider where you would go to safety, and be ready to follow the advice of emergency services.

To find out about local emergency plans, contact the local authority listed above. Be aware that they may not be able to give you any specific information immediately as developing reservoir emergency plans is a new responsibility.

If you would like to see information on how deep the water could get or how fast it could flow:

- View the estimates of the depth of flooding from reservoirs for this area
- View the estimates of the speed of flooding from reservoirs for this area.

This area may be at risk from other types of flooding:

- Check your risk of flooding from rivers and sea
- Check your risk of flooding from surface water.

Details of groundwater and surface water flooding are maintained and held by the LLFA (Essex County Council) for this area, they will be able to provide historic data for the area. Surface water flood risk maps are available on our website here: http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?lang=_e&topic=ufmfsw&layer=default&scale=10&x=548851&y=212152#x=548851&y=212152&scale=10 The data used to create these maps were from the LLFA and created nationally.

I have attached our Standard Notice which explains the permitted use of this information.

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Yours sincerely

Customers and Engagement Officer
Direct dial 01707 632468
Direct fax 01707 632610
Direct email HNLenquiries@environment-agency.gov.uk

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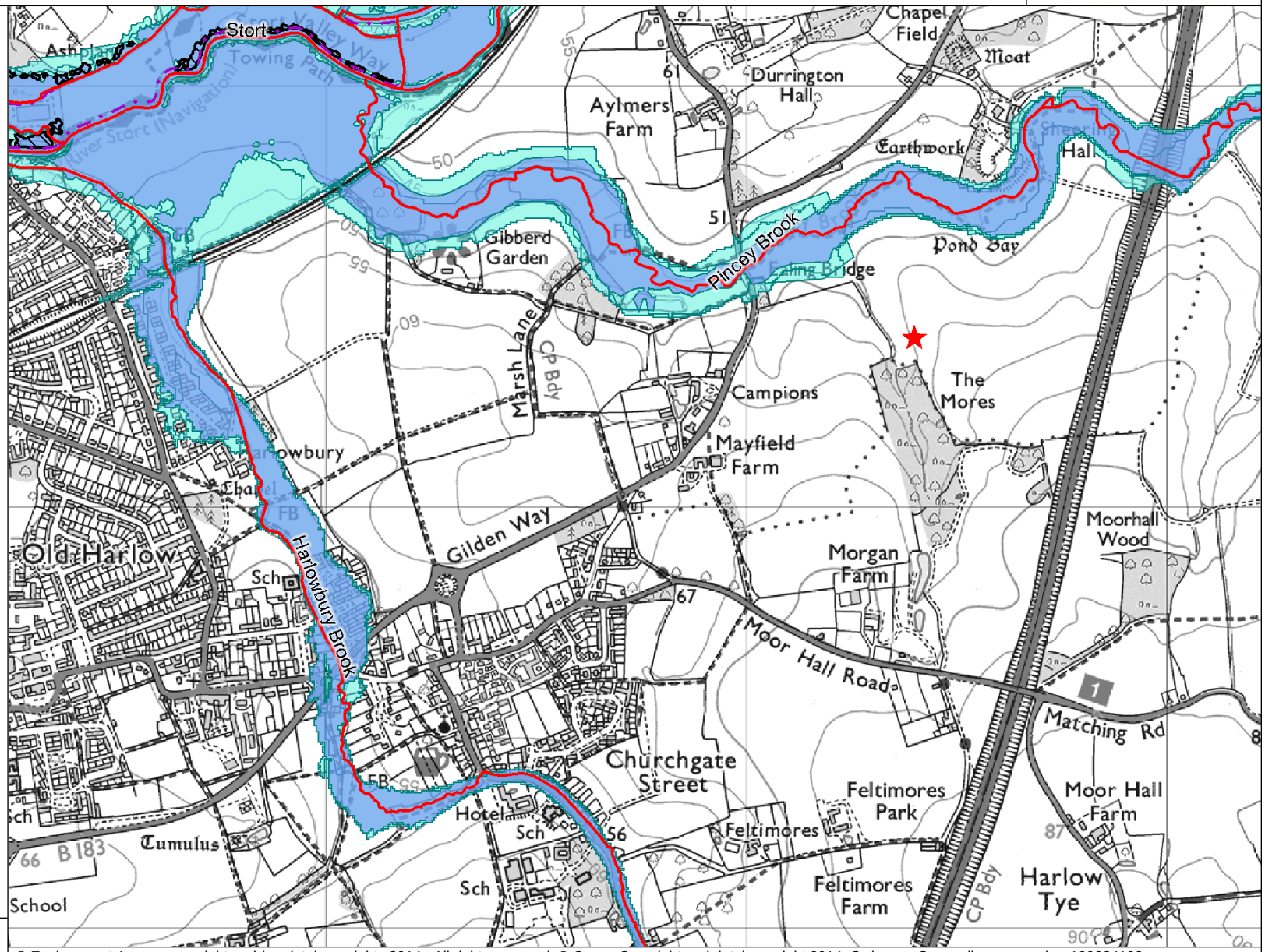
Flood zone map Created 24 December 2015 Ref: HNL/049609/JH

Environment Agency

Legend

- Sealed Main Rivers
- Flood Map - Defences
- Areas Benefiting from Flood Defences
- Flood Map - Flood Storage Areas
- Flood Map - Flood Zone 3
- Flood Map - Flood Zone 2



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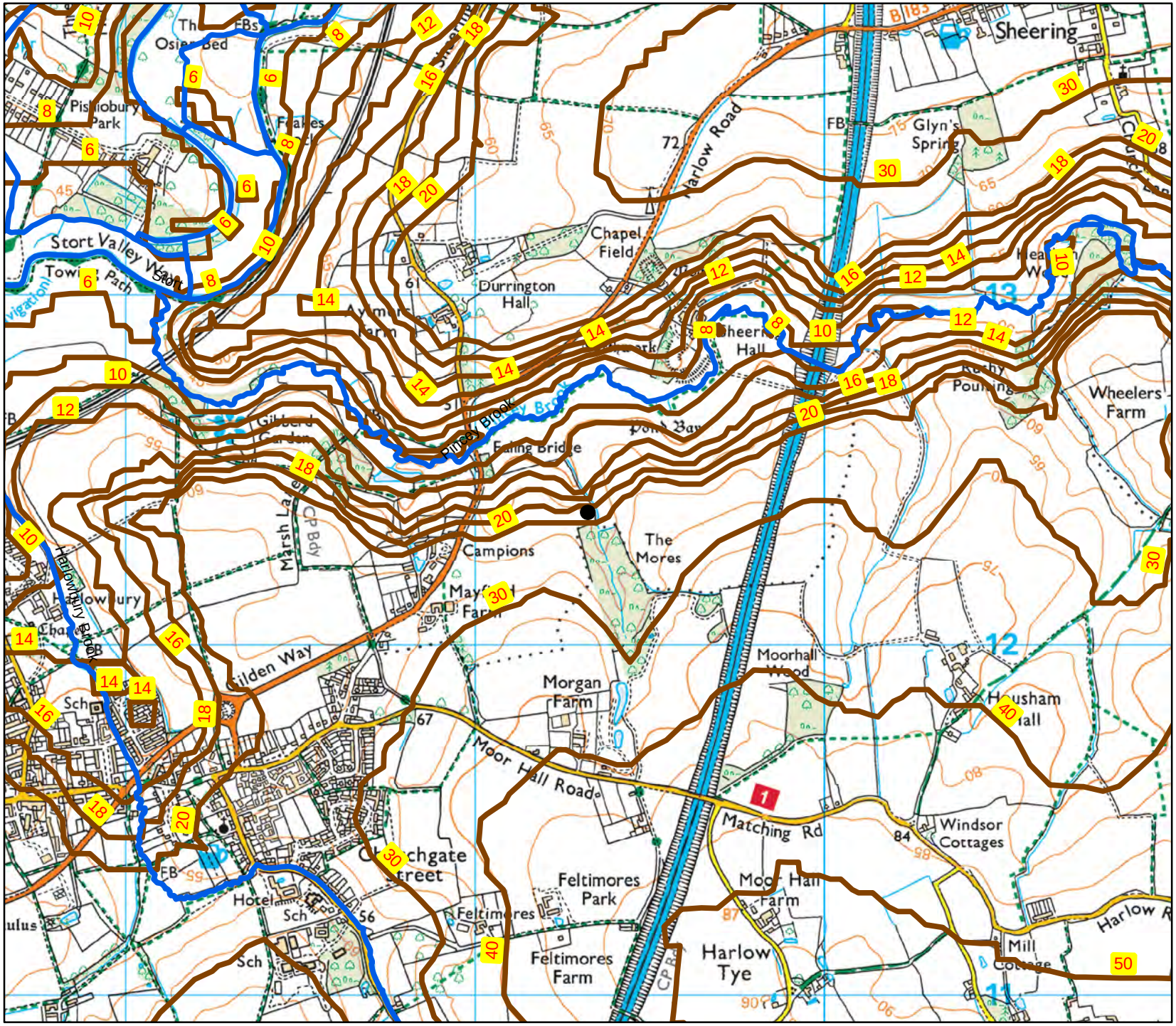
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Glyn's Spring
Chapel Field
Durrington Hall
Stort Valley Way
Pishobury Park
Stort
Pimpey Brook
Ealing Bridge
Wheelers Farm
The Mores
Campions
Mayfield Farm
Hallowbury Brook
Gilden Way
Morgan Farm
Moorhall Wood
Housham Hall
Moor Hall Road
Matching Rd
Windsor Cottages
Feltimores Park
Feltimores Farm
Moor Hall Farm
Harlow Tye
Mill Cottage
Harlow R
Hotel
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Marsh La
Gilbert Garden
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Sheering Hall
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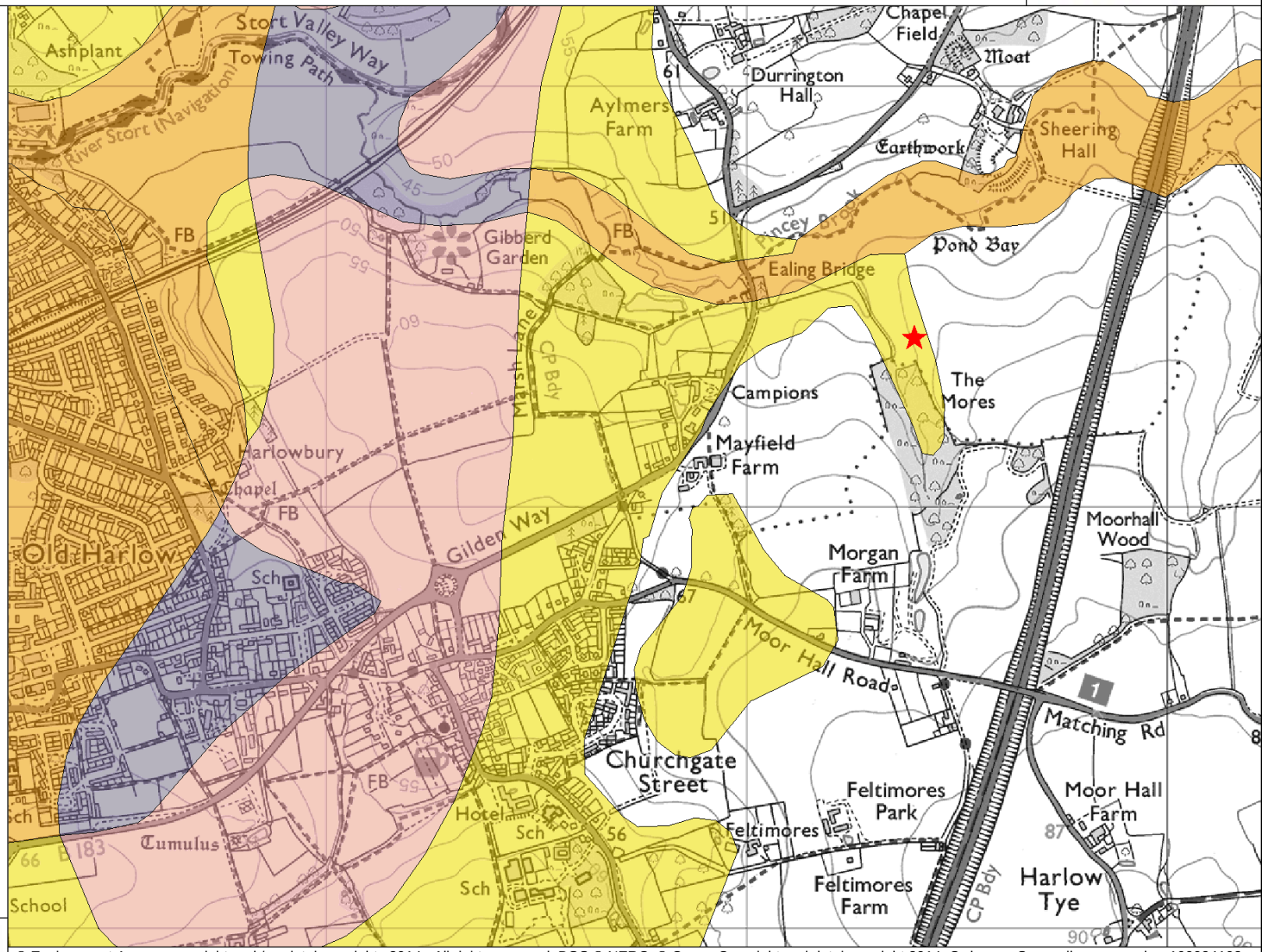
Groundwater vulnerability map Created 24 December 2015 Ref: HNL/049609/JH

Environment Agency

Legend

Groundwater Vulnerability Zones

- MAJOR AQUIFER HIGH
- MAJOR AQUIFER INTERMEDIATE
- MAJOR AQUIFER LOW
- MINOR AQUIFER HIGH
- MINOR AQUIFER INTERMEDIATE
- MINOR AQUIFER LOW



0 130 260 390 m.

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Our ref: HNL/049609/JH

Your ref:
B1279873/REA/UTL/RAM/JC/EA2

Date: 24 December 2015

Dear James Cullinane

Enquiry regarding Re: Harlow Eastern Access Improvements, M11 Junction 7a Flood Risk Assessment

Thank you for your enquiry which was received on 26 November 2015.

We respond to requests under the Freedom of Information Act 2000 and Environmental Information Regulations 2004.

The area in which your proposed development is located sits on top of London Clay, a rock layer of very low permeability. This layer of London Clay isolates the groundwater stored in the Chalk below. The level of the groundwater table in the Chalk is therefore not relevant to the flood risk in this area. However, the low permeability of the London Clay means the area has poor drainage. This means that any water retained in this layer or the soil above it may accumulate in low-lying areas and cause flooding. Following the Flood and Water Management Act 2010, Lead Local Flood Authorities are now responsible for the management of groundwater and surface water flooding. They also maintain a register of property flooding incidents. You may want to seek further advice Essex County Council, the LLFA in your area.

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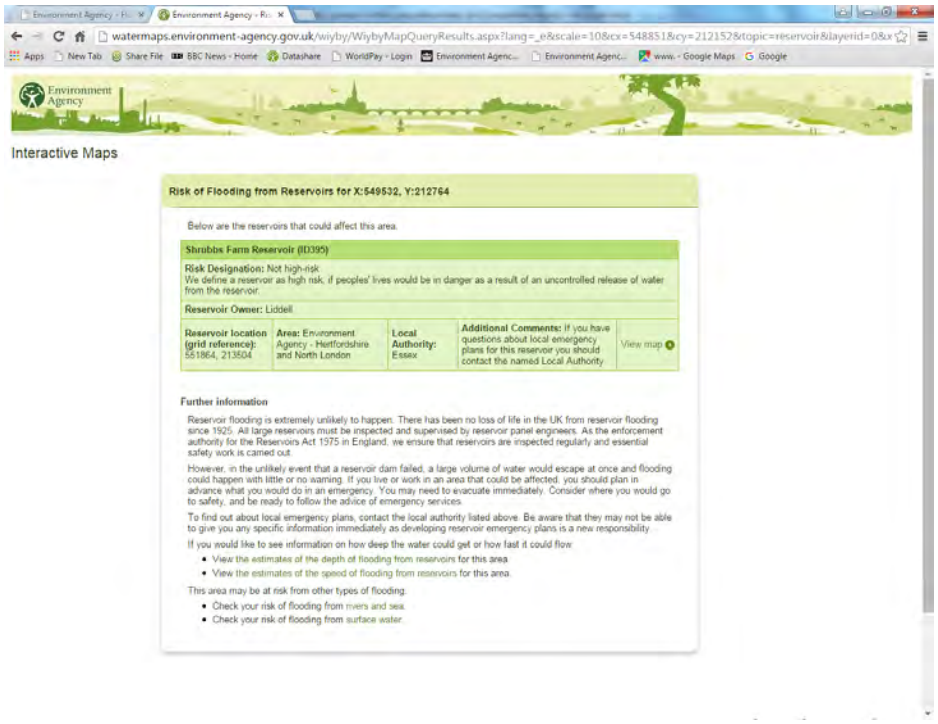

Interactive Maps

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Shrubbs Farm Reservoir (ID395)

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Reservoir Owner: Liddell

Reservoir location (grid reference):	Area:	Local Authority:	Additional Comments:	
551864, 213604	Environment Agency - Hertfordshire and North London	Essex	If you have questions about local emergency plans for this reservoir you should contact the named Local Authority	View map

Further information

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Yours sincerely

Customers and Engagement Officer
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Direct fax 01707 632610
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Flood zone map Created 24 December 2015 Ref: HNL/049609/JH

Environment Agency

Legend

- Sealed Main Rivers
- Flood Map - Defences
- Areas Benefiting from Flood Defences
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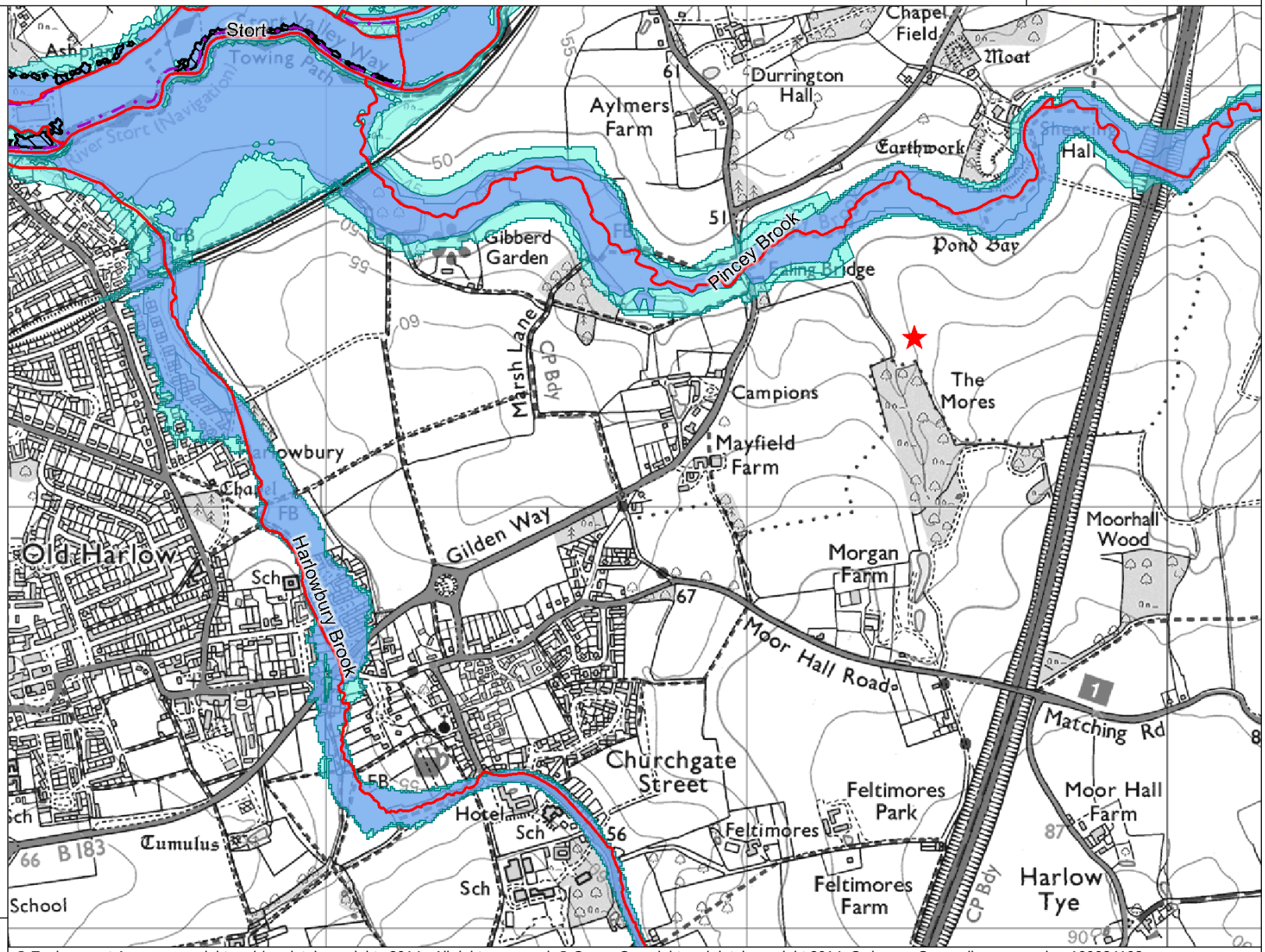

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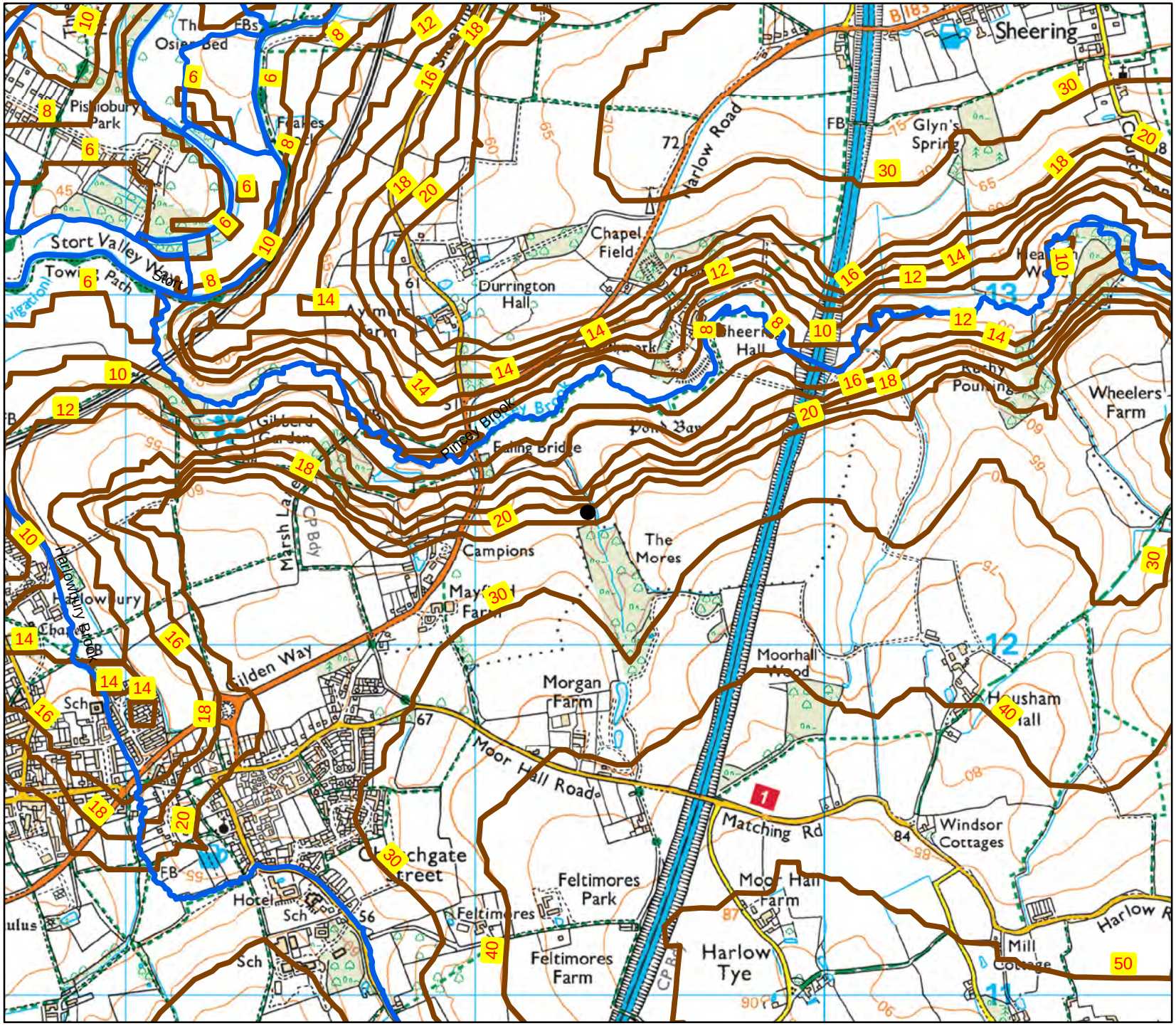
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Glyn's Spring
Chapel Field
Durrington Hall
Stort Valley Way
Pishobury Park
Stort
Pimpey Brook
Ealing Bridge
Wheelers Farm
The Mores
Campions
Mayfield Farm
Hallowbury Brook
Gilden Way
Morgan Farm
Moorhall Wood
Housham Hall
Moor Hall Road
Matching Rd
Windsor Cottages
Feltimores Park
Feltimores Farm
Moor Hall Farm
Harlow Tye
Mill Cottage
Harlow R
Hotel
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CP Bdy
Marsh La
Gilbert Garden
Pond Bay
Rushy Pouning
Sheering Hall
Osier Bed
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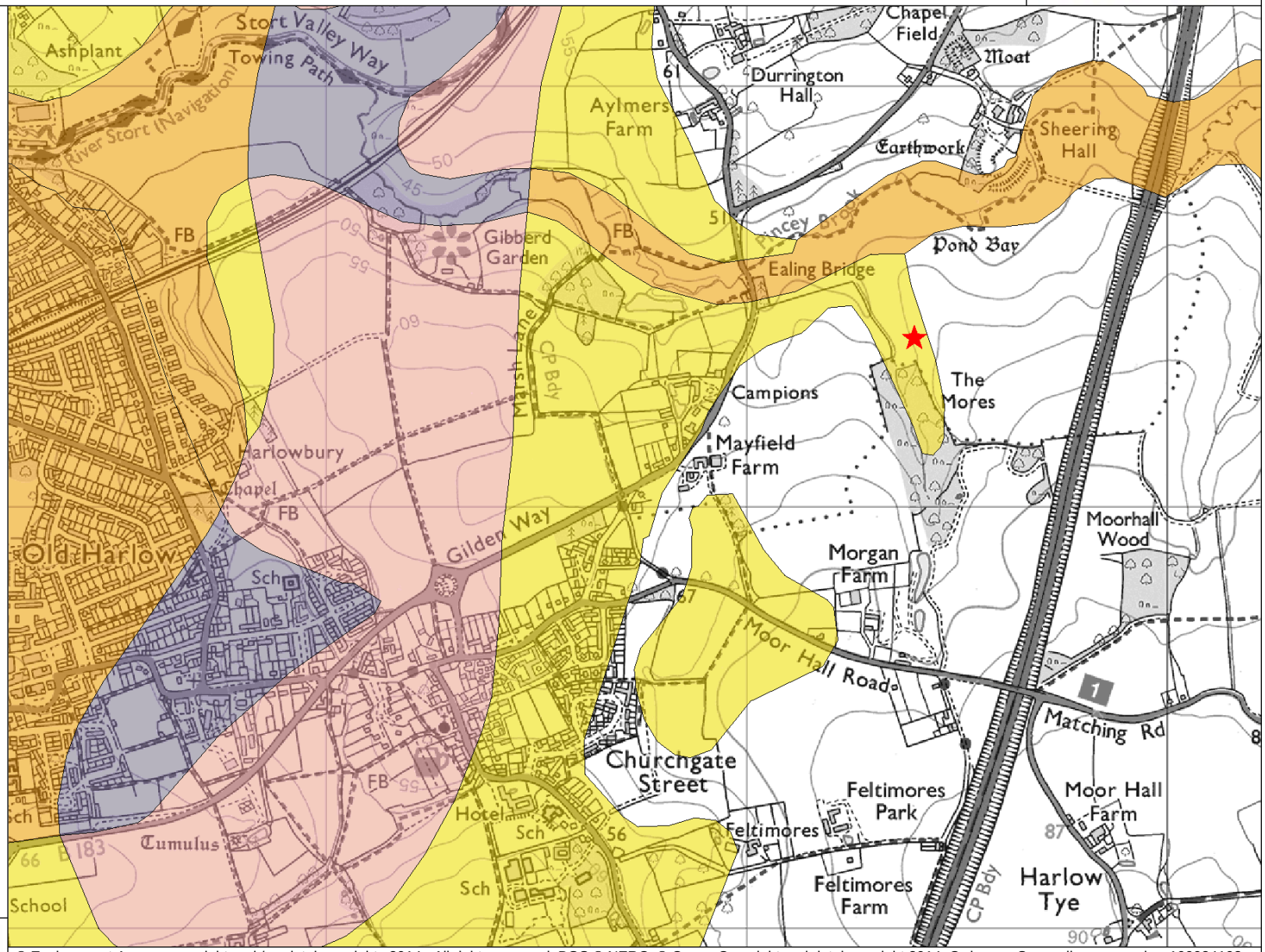
Groundwater vulnerability map Created 24 December 2015 Ref: HNL/049609/JH

Environment Agency

Legend

Groundwater Vulnerability Zones

- MAJOR AQUIFER HIGH
- MAJOR AQUIFER INTERMEDIATE
- MAJOR AQUIFER LOW
- MINOR AQUIFER HIGH
- MINOR AQUIFER INTERMEDIATE
- MINOR AQUIFER LOW



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Appendix B. Thames Water Assets and Historical Flood Report

Sewer Flooding

History Enquiry

Jacobs Engineering UK Ltd

Eskdale Road

Search address supplied M11 Junction 7A
Near Harlow

Your reference N/A

Our reference SFH/SFH Standard/2015_3203246

Received date **25 November 2015**

Search date **19 January 2016**

Thames Water Utilities Ltd

Property Searches
PO Box 3189
Slough SL1 4WW

DX 151280 Slough 13

T 0118 925 1504
E searches@thameswater.co.uk
I www.thameswater-propertysearches.co.uk

Registered in England and Wales
No. 2366661, Registered office
Clearwater Court, Vastern Road
Reading RG1 8DB

Sewer Flooding

History Enquiry

Search address supplied: M11 Junction 7A,Near Harlow

This search is recommended to check for any sewer flooding in a specific address or area

TWUL, trading as Property Searches, are responsible in respect of the following:-

(i) any negligent or incorrect entry in the records searched;

(ii) any negligent or incorrect interpretation of the records searched;

(iii) and any negligent or incorrect recording of that interpretation in the search report

(iv) compensation payments

Thames Water Utilities Ltd

Property Searches
PO Box 3189
Slough SL1 4WW

DX 151280 Slough 13

T 0118 925 1504
E searches@thameswater.co.uk
I www.thameswater-propertysearches.co.uk

Registered in England and Wales
No. 2366661, Registered office
Clearwater Court, Vastern Road
Reading RG1 8DB

Sewer Flooding

History Enquiry

History of Sewer Flooding

Is the requested address or area at risk of flooding due to overloaded public sewers?

The flooding records held by Thames Water indicate that there have been no incidents of flooding in the requested area as a result of surcharging public sewers.

For your guidance:

- A sewer is "overloaded" when the flow from a storm is unable to pass through it due to a permanent problem (e.g. flat gradient, small diameter). Flooding as a result of temporary problems such as blockages, siltation, collapses and equipment or operational failures are excluded.
- "Internal flooding" from public sewers is defined as flooding, which enters a building or passes below a suspended floor. For reporting purposes, buildings are restricted to those normally occupied and used for residential, public, commercial, business or industrial purposes.
- "At Risk" properties are those that the water company is required to include in the Regulatory Register that is presented annually to the Director General of Water Services. These are defined as properties that have suffered, or are likely to suffer, internal flooding from public foul, combined or surface water sewers due to overloading of the sewerage system more frequently than the relevant reference period (either once or twice in ten years) as determined by the Company's reporting procedure.
- Flooding as a result of storm events proven to be exceptional and beyond the reference period of one in ten years are not included on the At Risk Register.
- Properties may be at risk of flooding but not included on the Register where flooding incidents have not been reported to the Company.
- Public Sewers are defined as those for which the Company holds statutory responsibility under the Water Industry Act 1991.
- It should be noted that flooding can occur from private sewers and drains which are not the responsibility of the Company. This report excludes flooding from private sewers and drains and the Company makes no comment upon this matter.
- For further information please contact Thames Water on Tel: 0800 316 9800 or website www.thameswater.co.uk

Thames Water Utilities Ltd

Property Searches
PO Box 3189
Slough SL1 4WW

DX 151280 Slough 13

T 0118 925 1504
E searches@thameswater.co.uk
I www.thameswater-propertysearches.co.uk

Registered in England and Wales
No. 2366661, Registered office
Clearwater Court, Vastern Road
Reading RG1 8DB

Asset Location Search

James Cullinane
Jacobs Engineering UK Ltd
1180Eskdale Road
WINNERSH
WOKINGHAM
RG41 5TU

Search address supplied East Harrow

Your reference 647311

Our reference ALS/ALS Non Chargeable/2016_3231336

Search date 15 January 2016

You are now able to order your Asset Location Search requests online by visiting
www.thameswater-propertysearches.co.uk

Asset Location Search

Search address supplied: East Harrow,

Dear Sir / Madam

An Asset Location Search is recommended when undertaking a site development. It is essential to obtain information on the size and location of clean water and sewerage assets to safeguard against expensive damage and allow cost-effective service design.

The following records were searched in compiling this report: - the map of public sewers & the map of waterworks. Thames Water Utilities Ltd (TWUL) holds all of these.

This searchprovides maps showing the position, size of Thames Water assets close to the proposed development and also manhole cover and invert levels, where available.

Please note that none of the charges made for this report relate to the provision of Ordnance Survey mapping information. The replies contained in this letter are given following inspection of the public service records available to this company. No responsibility can be accepted for any error or omission in the replies.

You should be aware that the information contained on these plans is current only on the day that the plans are issued. The plans should only be used for the duration of the work that is being carried out at the present time. Under no circumstances should this data be copied or transmitted to parties other than those for whom the current work is being carried out.

Thames Water do update these service plans on a regular basis and failure to observe the above conditions could lead to damage arising to new or diverted services at a later date.

Contact Us

If you have any further queries regarding this enquiry please feel free to contact a member of the team on 0845 070 9148, or use the address below:

Thames Water Utilities Ltd
Property Searches
PO Box 3189
Slough
SL1 4WW

Email: searches@thameswater.co.uk
Web: www.thameswater-propertysearches.co.uk

Asset Location Search

Waste Water Services

Please provide a copy extract from the public sewer map.

The following quartiles have been printed as they fall within Thames' sewerage area:

TL4811NE
TL4711SE
TL4811NW
TL4812SE
TL4711SW
TL4711NE

Enclosed is a map showing the approximate lines of our sewers. Our plans do not show sewer connections from individual properties or any sewers not owned by Thames Water unless specifically annotated otherwise. Records such as "private" pipework are in some cases available from the Building Control Department of the relevant Local Authority.

Where the Local Authority does not hold such plans it might be advisable to consult the property deeds for the site or contact neighbouring landowners.

This report relates only to sewerage apparatus of Thames Water Utilities Ltd, it does not disclose details of cables and or communications equipment that may be running through or around such apparatus.

The sewer level information contained in this response represents all of the level data available in our existing records. Should you require any further Information, please refer to the relevant section within the 'Further Contacts' page found later in this document.

The following quartiles have not been printed as they contain no assets:

TL4912SW
TL4911NE
TL5012SW
TL4912NW
TL5012NW
TL4812NE
TL4912SE
TL4912NE

For your guidance:

- The Company is not generally responsible for rivers, watercourses, ponds, culverts or highway drains. If any of these are shown on the copy extract they are shown for information only.
- Any private sewers or lateral drains which are indicated on the extract of the public sewer map as being subject to an agreement under Section 104 of the Water

Asset Location Search

Industry Act 1991 are not an 'as constructed' record. It is recommended these details be checked with the developer.

Clean Water Services

Please provide a copy extract from the public water main map.

Following examination of our statutory maps, Thames Water has been unable to find any plans of water mains within this area. If you require a connection to the public water supply system, please write to:

New Connections / Diversions
Thames Water
Network Services Business Centre
Brentford
Middlesex
TW8 0EE

Tel: 0845 850 2777
Fax: 0207 713 3858
Email: developer.services@thameswater.co.uk

The following quartiles have not been printed as they are out of Thames' water catchment area. For details of the assets requested please contact the water company indicated below:

TL4811NE	Affinity Water
TL4912SW	Affinity Water
TL4911NE	Affinity Water
TL5012SW	Affinity Water
TL4711SE	Affinity Water
TL4912NW	Affinity Water
TL5012NW	Affinity Water
TL4812NE	Affinity Water
TL4811NW	Affinity Water
TL4912SE	Affinity Water
TL4812SE	Affinity Water
TL4912NE	Affinity Water
TL4711SW	Affinity Water
TL4711NE	Affinity Water

Affinity Water Ltd
Tamblin Way
Hatfield
AL10 9EZ

Asset Location Search

Tel: 0845 7823333

For your guidance:

- Assets other than vested water mains may be shown on the plan, for information only.
- If an extract of the public water main record is enclosed, this will show known public water mains in the vicinity of the property. It should be possible to estimate the likely length and route of any private water supply pipe connecting the property to the public water network.

Payment for this Search

There is no fee associated with this enquiry, and thus no payment is required.

Asset Location Search

Further contacts:

Waste Water queries

Should you require verification of the invert levels of public sewers, by site measurement, you will need to approach the relevant Thames Water Area Network Office for permission to lift the appropriate covers. This permission will usually involve you completing a TWOSA form. For further information please contact our Customer Centre on Tel: 0845 920 0800. Alternatively, a survey can be arranged, for a fee, through our Customer Centre on the above number.

If you have any questions regarding sewer connections, budget estimates, diversions, building over issues or any other questions regarding operational issues please direct them to our service desk. Which can be contacted by writing to:

Developer Services (Waste Water)
Thames Water
Clearwater Court
Vastern Road
Reading
RG1 8DB

Tel: 0845 850 2777
Email: developer.services@thameswater.co.uk

Clean Water queries

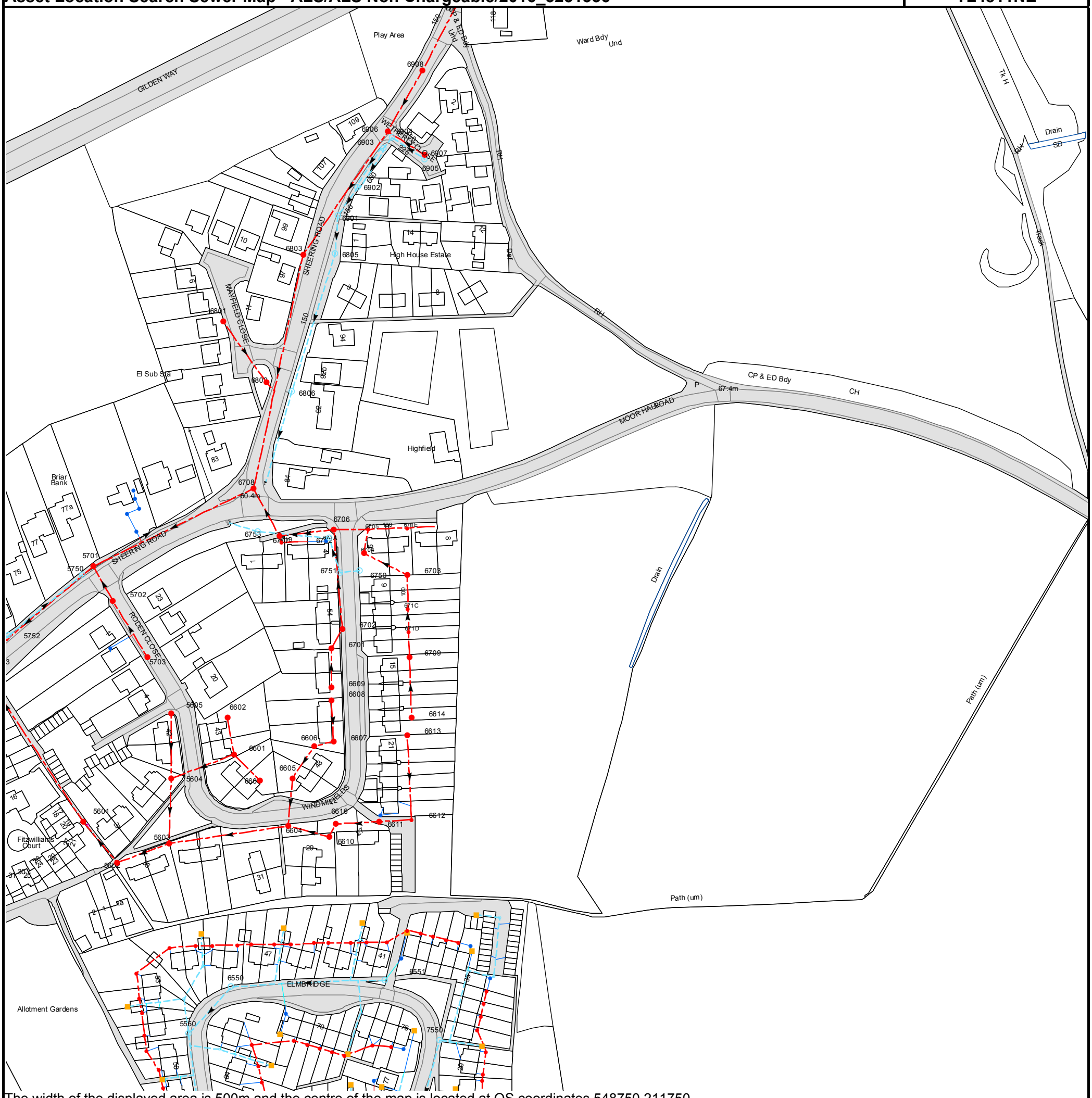
Should you require any advice concerning clean water operational issues or clean water connections, please contact:

Developer Services (Clean Water)
Thames Water
Clearwater Court
Vastern Road
Reading
RG1 8DB

Tel: 0845 850 2777
Email: developer.services@thameswater.co.uk

Asset Location Search Sewer Map - ALS/ALS Non Chargeable/2016_3231336

TL4811NE



The width of the displayed area is 500m and the centre of the map is located at OS coordinates 548750,211750

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

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NB. Levels quoted in metres Ordnance Newlyn Datum. The value -9999.00 indicates that no survey information is available

Manhole Reference	Manhole Cover Level	Manhole Invert Level
6753	n/a	n/a
571E	n/a	n/a
6706	n/a	n/a
6705	n/a	n/a
671E	n/a	n/a
571D	n/a	n/a
571C	n/a	n/a
571B	n/a	n/a
571A	n/a	n/a
6708	n/a	n/a
6806	n/a	n/a
6802	n/a	n/a
6801	n/a	n/a
6803	n/a	n/a
6805	n/a	59.79
6901	60.7	59.91
6902	60.98	59.98
6905	61.35	60.23
6907	61.62	59.92
6903	61.15	59.99
6904	60.85	60.04
6906	60.8	58.98
6908	n/a	58.29
5752	n/a	n/a
5750	n/a	n/a
5701	n/a	n/a
571F	n/a	n/a
5702	n/a	n/a
5703	n/a	n/a
5605	n/a	n/a
6707	n/a	n/a
671B	n/a	n/a
671A	n/a	n/a
6752	n/a	n/a
6608	n/a	n/a
6609	n/a	n/a
6701	n/a	n/a
6751	n/a	n/a
6702	n/a	n/a
6750	n/a	n/a
6704	n/a	n/a
6703	n/a	n/a
671C	n/a	n/a
671D	n/a	n/a
6709	n/a	n/a
6614	n/a	n/a
651H	n/a	n/a
6610	n/a	n/a
6607	n/a	n/a
6616	n/a	n/a
651F	n/a	212
651I	n/a	n/a
6611	n/a	n/a
661A	n/a	n/a
6551	n/a	207.68
651G	n/a	213
651M	n/a	n/a
651L	n/a	216
6613	n/a	n/a
6612	n/a	n/a
651J	n/a	n/a
651K	n/a	n/a
751B	n/a	n/a
751C	n/a	n/a
751F	n/a	218
751A	n/a	218.5
751K	n/a	n/a
751J	n/a	n/a
751I	n/a	n/a
751H	n/a	n/a
751G	n/a	218.5
751E	n/a	218.33
751D	n/a	222.33
5601	n/a	n/a
5602	n/a	n/a
551H	n/a	197.25
551E	n/a	n/a
551F	n/a	n/a
551C	n/a	n/a
5603	n/a	n/a
551I	n/a	197.25
5604	n/a	n/a
551G	n/a	200.2
5550	n/a	199.58
551J	n/a	199
551L	n/a	n/a
551K	n/a	n/a
6602	n/a	n/a
6550	n/a	201.11
6601	n/a	n/a
651A	n/a	201

Manhole Reference	Manhole Cover Level	Manhole Invert Level
651B	n/a	n/a
6603	n/a	n/a
651D	n/a	204.75
651Z	n/a	n/a
6604	n/a	n/a
651C	n/a	n/a
6605	n/a	n/a
651E	n/a	207.5
6606	n/a	n/a
551D	n/a	195.81
551B	n/a	n/a
551A	n/a	195.06
551M	n/a	n/a
651V	n/a	203.5
651W	n/a	n/a
651X	n/a	n/a
651R	n/a	206.74
651S	n/a	n/a
651T	n/a	n/a
651U	n/a	n/a
651Q	n/a	210.3
651P	n/a	n/a
651Y	n/a	215.3
651O	n/a	n/a
651N	n/a	213.5
7550	n/a	214.5
751L	n/a	217.28
751O	n/a	n/a
751N	n/a	n/a
751M	n/a	215.2

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Asset Location Search Sewer Map - ALS/ALS Non Chargeable/2016_3231336

TL4711SE

The width of the displayed area is 500m and the centre of the map is located at OS coordinates 547750,211250

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

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NB. Levels quoted in metres Ordnance Newlyn Datum. The value -9999.00 indicates that no survey information is available

Manhole Reference	Manhole Cover Level	Manhole Invert Level
9350	n/a	n/a
n/a	52.82	46.61
5350	n/a	n/a
5301	n/a	n/a
531A	n/a	n/a
5351	n/a	n/a
5352	n/a	n/a
6350	n/a	n/a
7350	n/a	n/a
n/a	n/a	n/a
8001	55.81	54.23
n/a	n/a	n/a
9001	54.61	53.3
8350	n/a	n/a

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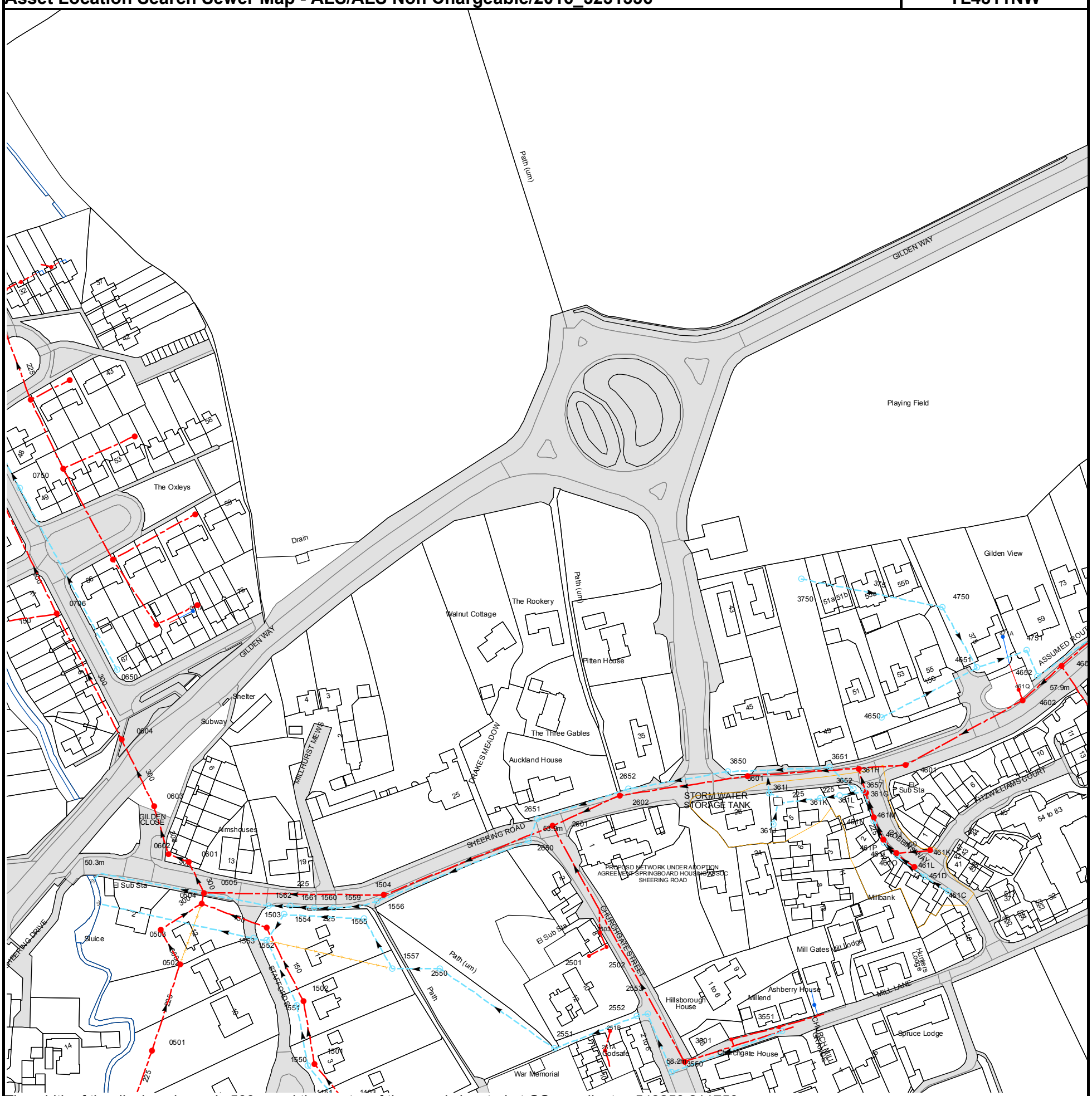
Asset Location Search Sewer Map - ALS/ALS Non Chargeable/2016_3231336

TL4811NW



The width of the displayed area is 500m and the centre of the map is located at OS coordinates 548250,211750

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

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NB. Levels quoted in metres Ordnance Newlyn Datum. The value -9999.00 indicates that no survey information is available

Manhole Reference	Manhole Cover Level	Manhole Invert Level
0803	n/a	n/a
081B	n/a	n/a
081A	n/a	n/a
0603	49.92	48.57
0604	n/a	n/a
0650	n/a	n/a
0702	n/a	n/a
0706	n/a	n/a
071A	n/a	n/a
0701	n/a	n/a
0703	n/a	n/a
0704	n/a	n/a
0750	n/a	n/a
0705	n/a	n/a
0801	n/a	n/a
0802	n/a	n/a
3551	n/a	n/a
251B	n/a	n/a
351B	n/a	n/a
2552	n/a	n/a
2553	n/a	n/a
351A	n/a	n/a
1557	n/a	n/a
2550	n/a	n/a
2501	n/a	n/a
2502	n/a	n/a
2503	n/a	n/a
1555	n/a	n/a
1559	n/a	n/a
1556	n/a	n/a
1504	n/a	n/a
451C	n/a	n/a
451D	n/a	n/a
461L	n/a	n/a
461O	n/a	n/a
461I	n/a	n/a
461K	n/a	n/a
461P	n/a	n/a
2650	n/a	n/a
461J	n/a	n/a
2601	n/a	n/a
361J	n/a	n/a
461N	n/a	n/a
2551	n/a	n/a
251A	n/a	n/a
3550	n/a	n/a
3501	n/a	n/a
351C	n/a	n/a
0501	n/a	n/a
0503	50.85	49.12
0602	50.04	48.69
0502	n/a	n/a
0601	50.01	48.81
0504	n/a	n/a
0505	50.28	48.87
1553	n/a	n/a
1552	n/a	n/a
1503	n/a	n/a
1562	n/a	n/a
1554	n/a	n/a
1561	n/a	n/a
1551	n/a	n/a
1502	n/a	n/a
1550	n/a	n/a
1501	n/a	n/a
1560	n/a	n/a
461Q	n/a	n/a
4602	n/a	n/a
4751	n/a	n/a
4652	n/a	n/a
4603	n/a	n/a
2651	n/a	n/a
461M	n/a	n/a
361K	n/a	n/a
361L	n/a	n/a
2602	n/a	n/a
361I	n/a	n/a
361G	n/a	n/a
3657	n/a	n/a
3652	n/a	n/a
2652	n/a	n/a
3601	n/a	n/a
3650	n/a	n/a
361H	n/a	n/a
3651	n/a	n/a
4601	n/a	n/a
4650	n/a	n/a
4651	n/a	n/a
471A	n/a	n/a
4750	n/a	n/a
3750	n/a	n/a

Manhole Reference	Manhole Cover Level	Manhole Invert Level

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Asset Location Search Sewer Map - ALS/ALS Non Chargeable/2016_3231336 | **TL4812SE**

The width of the displayed area is 500m and the centre of the map is located at OS coordinates 548750,212250

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

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NB. Levels quoted in metres Ordnance Newlyn Datum. The value -9999.00 indicates that no survey information is available

Manhole Reference	Manhole Cover Level	Manhole Invert Level
7001	61.45	59.95
8001	62.69	60.89
811A	n/a	n/a
8101	62.48	61.65

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Asset Location Search Sewer Map - ALS/ALS Non Chargeable/2016_3231336

TL4711SW

The width of the displayed area is 500m and the centre of the map is located at OS coordinates 547250,211250

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

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NB. Levels quoted in metres Ordnance Newlyn Datum. The value -9999.00 indicates that no survey information is available

Manhole Reference	Manhole Cover Level	Manhole Invert Level
3250	n/a	n/a
3201	n/a	n/a
321A	n/a	n/a
421A	n/a	n/a
4201	n/a	n/a
2303	n/a	n/a
241A	n/a	n/a
2305	n/a	n/a
231B	n/a	n/a
231A	n/a	n/a
2310	n/a	n/a
2309	n/a	n/a
3301	n/a	n/a
3350	n/a	n/a
3302	n/a	n/a
3351	n/a	n/a
3352	n/a	n/a
4303	n/a	n/a
4301	n/a	n/a
4351	n/a	n/a
4250	n/a	n/a
431B	n/a	n/a
431A	n/a	n/a
4451	n/a	n/a
4401	n/a	n/a
4350	n/a	n/a
4302	n/a	n/a
241B	n/a	n/a
241C	n/a	n/a
4405	n/a	n/a
341F	n/a	n/a
2401	62.65	60.81
441A	n/a	n/a
3403	n/a	n/a
341A	n/a	n/a
341E	n/a	n/a
2455	n/a	n/a
441B	n/a	n/a
341D	n/a	n/a
2450	n/a	n/a
3401	n/a	n/a
3450	n/a	n/a
2454	n/a	n/a
3402	n/a	n/a
4403	n/a	n/a
4402	n/a	n/a
3451	n/a	n/a
4452	n/a	n/a
4450	n/a	n/a
4404	n/a	n/a
341G	n/a	n/a
341B	n/a	n/a
241D	n/a	n/a
341C	n/a	n/a
1403	n/a	n/a
251I	n/a	n/a
251H	n/a	n/a
0201	n/a	n/a
0303	n/a	n/a
1355	n/a	n/a
1251	n/a	n/a
1401	n/a	n/a
1451	n/a	n/a
1450	n/a	n/a
1150	n/a	n/a
1452	n/a	n/a
1350	n/a	n/a
1352	n/a	n/a
1351	n/a	n/a
1301	n/a	n/a
1250	n/a	n/a
1353	n/a	n/a
1454	n/a	n/a
1453	n/a	n/a
1402	n/a	n/a
1354	n/a	n/a
131B	n/a	n/a
131A	n/a	n/a
131C	n/a	n/a
1356	n/a	n/a
1357	n/a	n/a
2302	63.55	62.1
2301	n/a	n/a
2451	n/a	n/a
041A	n/a	n/a
0101	n/a	n/a
0251	n/a	n/a
0102	n/a	n/a
0150	n/a	n/a
0350	n/a	n/a
0250	n/a	n/a

Manhole Reference	Manhole Cover Level	Manhole Invert Level
0302	n/a	n/a
0301	n/a	n/a
0151	n/a	n/a

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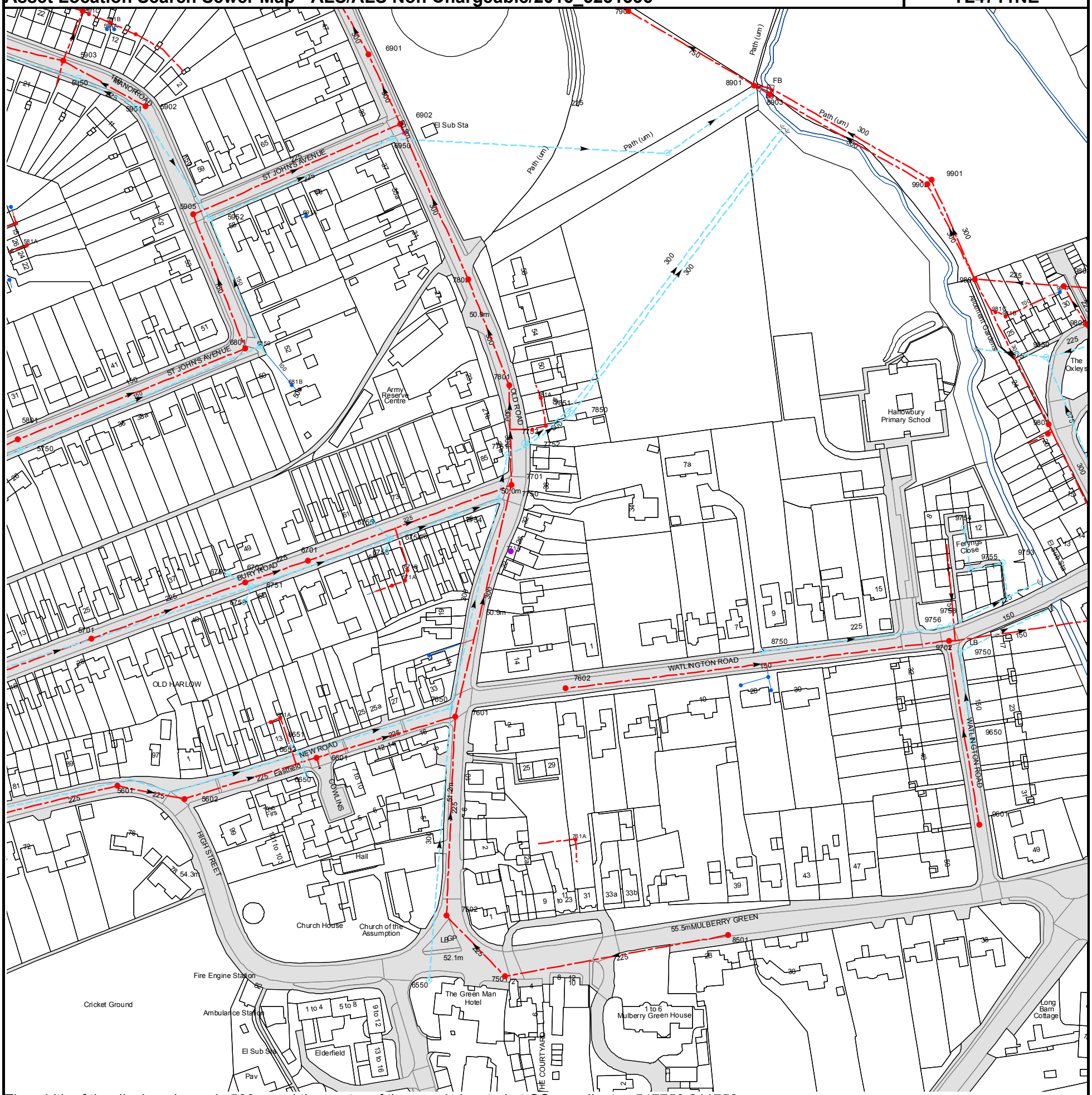
Asset Location Search Sewer Map - ALS/ALS Non Chargeable/2016_3231336

TL4711NE



The width of the displayed area is 500m and the centre of the map is located at OS coordinates 547750,211750

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NB. Levels quoted in metres Ordnance Newlyn Datum. The value -9999.00 indicates that no survey information is available

Manhole Reference	Manhole Cover Level	Manhole Invert Level
9850	n/a	n/a
9802	48.56	47.7
981B	n/a	n/a
981C	n/a	n/a
981A	n/a	n/a
981D	n/a	n/a
9804	48.35	47.5
9801	48.52	47.22
9902	48.09	46.98
9901	48.09	46.98
8903	47.74	46.54
8901	47.99	46.44
9650	n/a	n/a
861B	n/a	n/a
861A	n/a	n/a
861C	n/a	n/a
8750	n/a	n/a
9750	n/a	n/a
9702	n/a	n/a
9756	n/a	n/a
9758	n/a	n/a
9755	n/a	n/a
9753	n/a	n/a
9754	n/a	n/a
9853	n/a	n/a
9803	n/a	n/a
6801	n/a	n/a
6850	n/a	n/a
7802	51.39	47.52
5952	n/a	n/a
691A	n/a	n/a
5905	n/a	n/a
891B	n/a	n/a
6950	n/a	n/a
6902	50.94	46.95
5951	n/a	n/a
5902	n/a	n/a
6901	50.4	46.78
591D	n/a	n/a
7901	49.15	46.44
581B	n/a	n/a
591E	n/a	n/a
591F	n/a	n/a
581A	n/a	n/a
5903	n/a	n/a
5950	n/a	n/a
5801	n/a	n/a
5750	n/a	n/a
5701	n/a	n/a
5601	n/a	n/a
5602	54.61	53.16
6752	n/a	n/a
6750	n/a	n/a
6702	n/a	n/a
6751	n/a	n/a
661B	n/a	n/a
661A	n/a	n/a
6651	n/a	n/a
681B	n/a	n/a
6652	n/a	n/a
6650	n/a	n/a
6701	n/a	n/a
5901	n/a	n/a
591C	n/a	n/a
591A	n/a	n/a
591B	n/a	n/a
591G	n/a	n/a
8501	n/a	n/a
9601	n/a	n/a
6550	n/a	n/a
7501	n/a	n/a
7502	51.74	50.04
761A	n/a	n/a
6601	52.86	51.02
7601	51.28	48.91
7650	n/a	n/a
7602	n/a	n/a
671C	n/a	n/a
671D	n/a	n/a
671A	n/a	n/a
671B	n/a	n/a
771A	n/a	n/a
6753	n/a	n/a
6754	n/a	n/a
6755	n/a	n/a
7754	n/a	n/a
7750	n/a	n/a
7701	50.07	48.16
7751	n/a	n/a
7752	n/a	n/a
7753	n/a	n/a

Manhole Reference	Manhole Cover Level	Manhole Invert Level
7854	n/a	n/a
7853	n/a	n/a
7850	n/a	n/a
7851	n/a	n/a
781A	n/a	n/a
7801	50.15	47.87

The position of the apparatus shown on this plan is given without obligation and warranty, and the accuracy cannot be guaranteed. Service pipes are not shown but their presence should be anticipated. No liability of any kind whatsoever is accepted by Thames Water for any error or omission. The actual position of mains and services must be verified and established on site before any works are undertaken.

ALS Sewer Map Key

Public Sewer Types (Operated & Maintained by Thames Water)

Foul: A sewer designed to convey waste water from domestic and industrial sources to a treatment works.

Surface Water: A sewer designed to convey surface water (e.g. rain water from roofs, yards and car parks) to rivers or watercourses.

Combined: A sewer designed to convey both waste water and surface water from domestic and industrial sources to a treatment works.

Trunk Surface Water

Trunk Foul

Storm Relief

Trunk Combined

Vent Pipe

Bio-solids (Sludge)

Proposed Thames Surface Water Sewer

Proposed Thames Water Foul Sewer

Gallery

Foul Rising Main

Surface Water Rising Main

Combined Rising Main

Sludge Rising Main

Proposed Thames Water Rising Main

Vacuum

Sewer Fittings

A feature in a sewer that does not affect the flow in the pipe. Example: a vent is a fitting as the function of a vent is to release excess gas.

Air Valve

Dam Chase

Fitting

Meter

Vent Column

Operational Controls

A feature in a sewer that changes or diverts the flow in the sewer. Example: A hydrobrake limits the flow passing downstream.

Control Valve

Drop Pipe

Ancillary

Weir

End Items

End symbols appear at the start or end of a sewer pipe. Examples: an Undefined End at the start of a sewer indicates that Thames Water has no knowledge of the position of the sewer upstream of that symbol, Outfall on a surface water sewer indicates that the pipe discharges into a stream or river.

Outfall

Undefined End

Inlet

Other Symbols

Symbols used on maps which do not fall under other general categories

Public/Private Pumping Station

Change of characteristic indicator (C.O.C.I.)

Invert Level

Summit

Areas

Lines denoting areas of underground surveys, etc.

Agreement

Operational Site

Chamber

Tunnel

Conduit Bridge

Other Sewer Types (Not Operated or Maintained by Thames Water)

Foul Sewer

Surface Water Sewer

Combined Sewer

Gulley

Culverted Watercourse

Proposed

Abandoned Sewer

Notes:

1) All levels associated with the plans are to Ordnance Datum Newlyn.

2) All measurements on the plans are metric.

3) Arrows (on gravity fed sewers) or flecks (on rising mains) indicate direction of flow.

4) Most private pipes are not shown on our plans, as in the past, this information has not been recorded.

5) 'na' or '0' on a manhole level indicates that data is unavailable.

6) The text appearing alongside a sewer line indicates the internal diameter of the pipe in milimetres. Text next to a manhole indicates the manhole reference number and should not be taken as a measurement. If you are unsure about any text or symbology present on the plan, please contact a member of Property Insight on 0845 070 9148.

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Appendix C. Affinity Water Assets

Affinity Water

Harlow Eastern Access Improvements

14/01/2010

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1:5,500

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This map was created by the Affinity Water Geographical Analysis Team, Tamblin Way, Hatfield, AL10 9EZ
Page Size = A3

- Distribution Main
- Asbestos Distribution Main
- Abandoned Main
- Asbestos Abandoned Main
- Adit / Tunnel
- Cable
- Hydrant
- Fitting
- Easement
- Company Boundary

Appendix D. Pincey Brook Design Flood Hydrology Report

M11 Junction 7A

Essex County Council

Pincey Brook Design Flood Hydrology

Document history and status

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Jacobs U.K. Limited

1180 Eskdale Road
Winnersh, Wokingham
Reading RG41 5TU
United Kingdom
T +44 (0)118 946 7000
F +44 (0)118 946 7001
www.jacobs.com

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1. Introduction

Jacobs are supporting Essex County Council (ECC) in the delivery of its objectives to improve the highway network across Essex. ECC is developing a proposal for improving access to and from the M11 in the Harlow area. The project is for the provision of a new motorway junction (Junction 7A) on the M11 between existing Junctions 7 and 8, a proposed link road to Sheering Road (B183) linking the M11 to Harlow, and proposed widening and improvement works to Sheering Road/Gilden Way (B183). This report summarises the hydrological analysis undertaken for the hydraulic modelling of the Pincey Brook and one unnamed tributary, to inform the M11 Junction 7A Flood Risk assessment.

2. Catchment Description

2.1 Pincey Brook catchment

The Pincey Brook overall catchment boundary, sub-catchments and model extents are shown on Figures A.1-2 in Annex A. The Pincey Brook flows in a southerly direction from its northernmost point near Stanstead Airport to its confluence with the River Stort located north-east of Harlow. The catchment is essentially rural with an URBEXT2000 catchment descriptor values up to 0.027. The main settlements within the catchment boundary are Takeley, Hatfield Broad Oak and Hatfield Heath. A part of Stanstead Airport is located within the northern end of the catchment. The topography of the catchment varies from 110m AOD at the upstream extent, to approximately 50mAOD at the downstream end.

There is a gauging station located on the Pincey Brook within the model extent between the M11 crossing and the Sheering Road crossing (Gauging Station No. 38026 - Sheering Hall). The gauging station record consists of water levels and flows (based on a stage-discharge rating). This gauging station is described in further detail in Section 4.2.

According to the British Geological Survey (BGS) online map viewer, the bedrock geology within the Pincey Brook catchment primarily consists of London Clay Formation (Clay, Silt and Sand). However, in the immediate vicinity of the proposed link road development there is a variety of bedrock geology including:

(1) London Clay Formation (Clay, Silt and Sand) which is sedimentary bedrock.

(2) Thanet Sand Formation and Lambeth Group (Clay, silt and sand).

(3) Lewes Nodular Chalk Formation and Seaford Chalk Formation (undifferentiated) which is also sedimentary bedrock according to the BGS website.

The latter two formations are located just downstream of Sheering Hall gauging station and so should not affect the gauged flows.

The superficial geology consists primarily of the Lowestoft Formation. According to the BGS website the Lowestoft Formation forms an extensive sheet of chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content. The carbonate content of the till matrix is about 30%. This superficial deposit may be permeable at locations but on the whole is not conducive to extensive infiltration. In the immediate vicinity of the proposed link road development there is a variety of superficial strata including:

(1) Alluvium (Clay, Silt, Sand And Gravel) which follow the flow path of the Pincey Brook.

(2) Head (Clay, Silt, Sand And Gravel).

(3) Lowestoft Formation previously described.

The Alluvium and Head geology is found all along the flow path of the Pincey Brook.

Referring to the Environment Agency (EA) online groundwater maps the majority of the Pincey Brook catchment does not contain an aquifer of significance. However, a portion of the proposed road development (i.e. Gilden Way) intersects “Principal” and “Secondary A” classified aquifers. A “Principal” Aquifer contains layers of rock or drift deposits that have high intergranular and/or fracture permeability which means they usually provide a high level of water storage. According to the EA website they may support water supply and/or river base flow on a strategic scale. According to the EA website a “Secondary A” aquifer consists of permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. Secondary A aquifers are generally aquifers formerly classified as minor aquifers.

The proposed development along Gilden Way also straddles the “minor aquifer intermediate“ groundwater vulnerability zone. Hence, the bedrock in the vicinity of Gilden Way may be a productive aquifer in places.

2.2 Inflow Locations and Hydrological Catchment Descriptors

Six hydrological inflows have been defined along the model extent. These are situated at the upstream boundaries of the model extent, confluences of significant tributaries into the model extent or where the watercourse intersects existing and proposed highway infrastructure (e.g. road crossing watercourse via culvert or bridge). Figure A.2 in Annex A shows the inflow locations along the Pincey Brook and unnamed tributary from The Mores woodland in addition to the sub-catchment boundaries manually delineated using the 1:25,000 scale Ordnance Survey mapping. There are four point inflow locations and two lateral inflow locations. Lateral inflows are linear features that spread an inflow over a section of the watercourse model extent as opposed to a specific point location.

The hydrological inflow and flow estimate locations are tabulated in Table 2.1 below. The inflow locations are where the hydraulic modellers should apply the hydrological inflows into the hydraulic model. The flow estimate locations are the points along the watercourses for which the total flow has been estimated based on a catchment boundary delineated to that point. These points can be found on Figure A.2 in Annex A where the catchment boundaries intersect the modelled watercourses.

Table 2.1 Pincey Brook Inflow Locations with Flow Estimate Location Coordinates

Watercourse and Inflow ID	Inflow Locations (midpoint of lateral inflows)		Type (point or lateral inflow)	Flow Estimate Location	
	Easting (m)	Northing (m)		Easting (m)	Northing (m)
PB1	550577	212953	Point	550167	212949
PB2	550098	212845	Point	549979	212806
PB3	549391	212176	Point	549187	212640
PB4	549077	212628	Point	548998	212568
Lateral 1	549645	212742	Lateral	549187	212646
Lateral 2	548599	212778	Lateral	548110	212799

In order to determine flow estimates in accordance with the Flood Estimation Handbook (Centre for Ecology & Hydrology, 1999 and later updates) hydrological catchment descriptors are required.

For each inflow the contributing sub-catchment was manually delineated using contours on the OS 1:25.000 scale mapping. The manually delineated sub-catchment areas for each of the inflow points were compared with the FEH CD-ROM automatically delineated catchment areas as a sense check. This comparison is presented in Table 2.2 below. The manually delineated boundaries were adopted in the flow estimation process.

Table 2.2 Pincey Brook Manually Delineated Sub-Catchment Areas and FEH Catchment Areas

Variable	Pincey Brook					Unnamed Watercourse
	PB1	PB2	Lateral 1	PB4	Lateral 2	PB3
Sub-Catchment Area (km^2) (Manually Delineated)	50.30	1.08	0.93	0.27	0.71	0.57
Total Catchment Area (km^2) (Manually Delineated)	50.30	51.38	52.31	53.15	53.86	0.57
Total Catchment Area (km^2) (From FEH CD-ROM)	51.12	51.83	52.84	53.83	54.6	0.71
Percentage Difference (%)	-1.60	-0.87	-1.00	-1.26	-1.35	-24.60

To derive estimates of the catchment descriptors for individual subcatchments, in general an area weighting procedure was applied as described in the FEH. As an exception FEH suggests that DPLBAR can be estimated using the regression equation: DPLBAR = $AREA^{0.548}$.

The catchment descriptors that were manually estimated for the Pincey Brook sub-catchments are provided in Table 2.4. The FEH catchment descriptors from the FEH CD-ROM are presented in Table 2.3 for comparison.

Table 2.3 FEH Catchment Descriptors from the FEH CD-ROM

Inflow Location	AREA	BFI-HOST	DPLBAR	DPSBAR	PROP-WET	SAAR	URBEXT 1990	URBEXT 2000	FARL	FPEXT
	(km^2)	(-)	(km)	(m/km)	(-)	(mm)	(-)	(-)	(-)	(-)
PB1	51.12	0.387	9.77	23.60	0.31	599	0.0131	0.0274	0.98	0.090
PB2	51.83	0.386	9.86	23.70	0.31	599	0.0129	0.0271	0.98	0.090
Lateral 1	52.84	0.388	10.78	24.10	0.31	599	0.0129	0.0266	0.98	0.089
PB4	53.83	0.390	10.97	24.30	0.31	599	0.0127	0.0261	0.98	0.088
Lateral 2	54.60	0.395	11.88	24.50	0.31	598	0.0126	0.0258	0.98	0.088
PB3	0.71	0.462	1.03	34.70	0.31	588	0	0	1.00	0.032

Table 2.4 Manually Estimated Catchment Descriptors

Inflow Location	AREA	BFI-HOST	DPLBAR	DPSBAR	PROP-WET	SAAR	URBEXT 1990	URBEXT 2000	FARL	FPEXT
	(km^2)	(-)	(km)	(m/km)	(-)	(mm)	(-)	(-)	(-)	(-)
PB1	50.30	0.387	9.77	23.60	0.31	599	0.0131	0.0274	0.98	0.090
PB2	51.38	0.340	1.04	28.31	0.31	599	0.0037	0.0133	0.98	0.090
Lateral 1	52.31	0.497	0.96	18.15	0.31	599	0.0129	0.0266	0.98	0.089
PB4	53.15	0.462	0.49	23.36	0.31	599	0.0127	0.0260	0.98	0.088
Lateral 2	53.86	0.462	0.83	28.24	0.31	599	0.0129	0.0270	0.98	0.088
PB3	0.57	0.462	1.03	34.70	0.31	588	0	0	1.00	0.032

Table 2.5 below describes the presence of any significant land-use or catchment factors that could influence the runoff rates from the contributing sub-catchments to the Pincey Brook and therefore the hydrological inflow estimates.

Table 2.5 Pincey Brook Flood Hydrology Catchment Factors

Factors	Comment	Potential Significance
Reservoir/lake	There are no significant lakes or man-made reservoirs on the modelled Pincey Brook catchment. There appear to be no significant lakes along the entire Pincey Brook upstream of the model extent. This is reflected in the FARL value at the upstream Pincey Brook model boundary of 0.985.	There should be a minimal routing effect in the catchment
Urban	All sub-catchments contributing to the Pincey Brook watercourse alignment of interest are essentially rural with URBEXT2000 values of up to 0.027.	Negligible effect on catchment runoff.
Land-use	The sub-catchments contributing to the Pincey Brook are essentially rural. There are some small settlements in the upstream catchment namely at Takeley, Hatfield Broad Oak and Hatfield Heath. Stanstead Airport is located at the upstream end of the catchment. According to the Cranfield Soilscapes website land-use comprises of some arable grassland, lime-rich loamy and clayey soils with base-rich pastures and classic chalky boulder clay ancient woodlands (http://www.landis.org.uk/soilscapes/)	No particular effects

Factors	Comment	Potential Significance
Soils/Geology	The primary soil type is lime-rich loamy and clayey soils with impeded drainage. (http://www.landis.org.uk/soilscapes/) The topography of the catchments varies from 110mAOD at the upstream extent, to approximately 50mAOD at the downstream end. BFIHOST ranges between 0.340 – 0.497 (classed as 'impermeable' in FEH) along the Pincey Brook with a value of 0.462 along the unnamed watercourse. SPRHOST ranges between 46.3 – 47.1 along the Pincey Brook with a value of 38.8 for the unnamed watercourse.	Possible increase in runoff during storm events due to impeded drainage conditions of soils.

3. Hydrometric Data Review

3.1 Rainfall Data

Rainfall data recorded at 15 minute intervals is available at two tipping bucket rain gauges within the Pincey Brook catchment located in Takeley and Hatfield Heath (Grid References provided in Table 3.1 below). Rainfall data was also made available for Widford, Thornwood and Moreton rain gauges. However, the rainfall data from these three rain gauges was disregarded as they are located well outside the Pincey Brook catchment. Figure C.1 in Annex C illustrates the locations of the rain gauges. The two chosen rainfall gauges, Takeley and Hatfield Heath, give relatively good coverage of the Pincey Brook catchment given that Takeley is located in the north of the catchment and Hatfield Heath located towards the south. The two rain gauges are 7.6 kilometres apart. Rainfall data was obtained for four rainfall events that occurred on 18/01/2011, 03/05/2012, 20/12/2012 and 07/02/2014 respectively. All these events were recorded as giving the highest water levels in their hydrometric year at the Sheering Hall gauging station (38026) situated on the model extent.

Cumulative rainfall plots of the selected rainfall events for both rain gauges are presented in Figures 3.1 to 3.4 to provide insight into the quality and spatial variability of the rainfall data. Both rain gauges capture the rainfall events well without an obvious consistent undercatch in one gauge compared to the other. It suggests that differences between the rainfall totals are probably due to spatial variation in the storms rather than undercatch.

Table 3.1 Rain Gauge Locations Within Pincey Brook Catchment

Rain Gauge	National Grid Reference
Takeley	TL 54820 21110
Hatfield Heath	TL 52375 14121

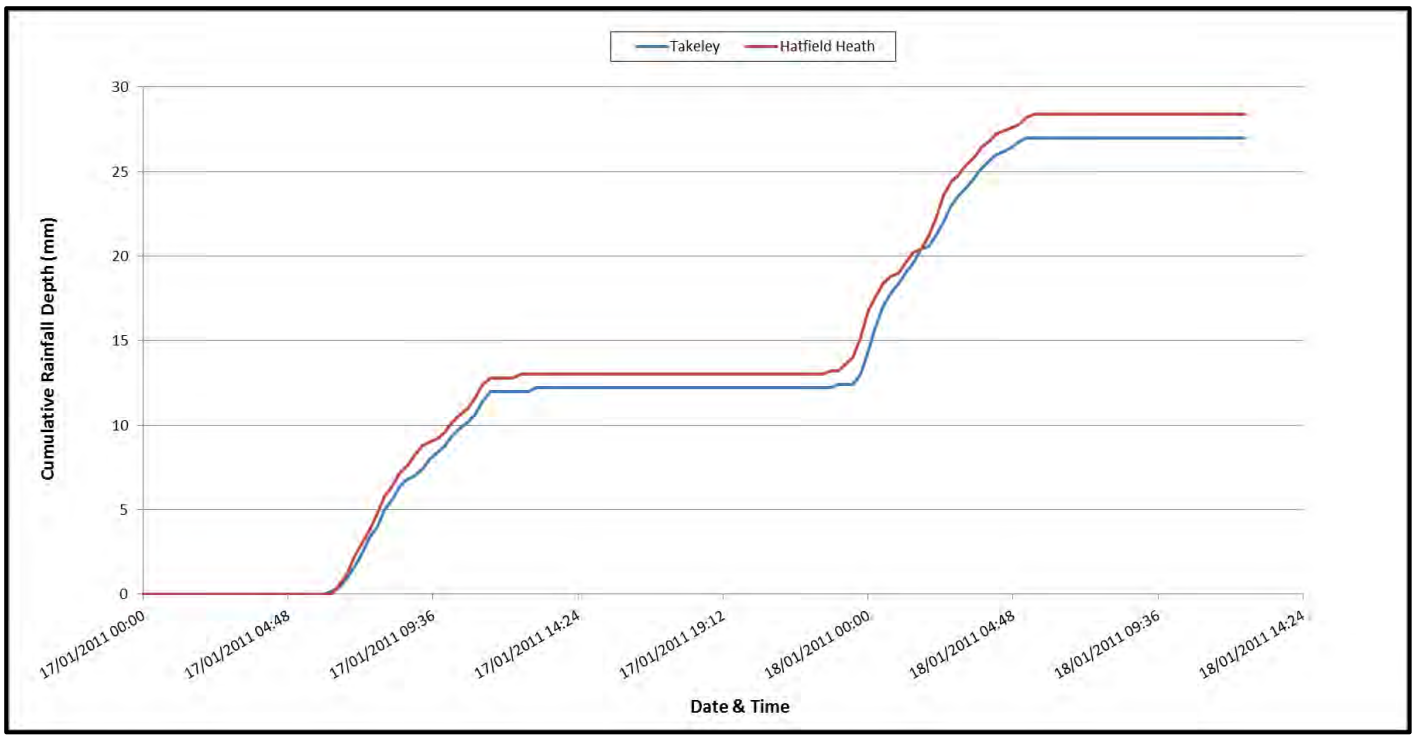


Figure 3.1 Cumulative Rainfall Plot for the 18/01/2011 Rainfall Event (Event 1)

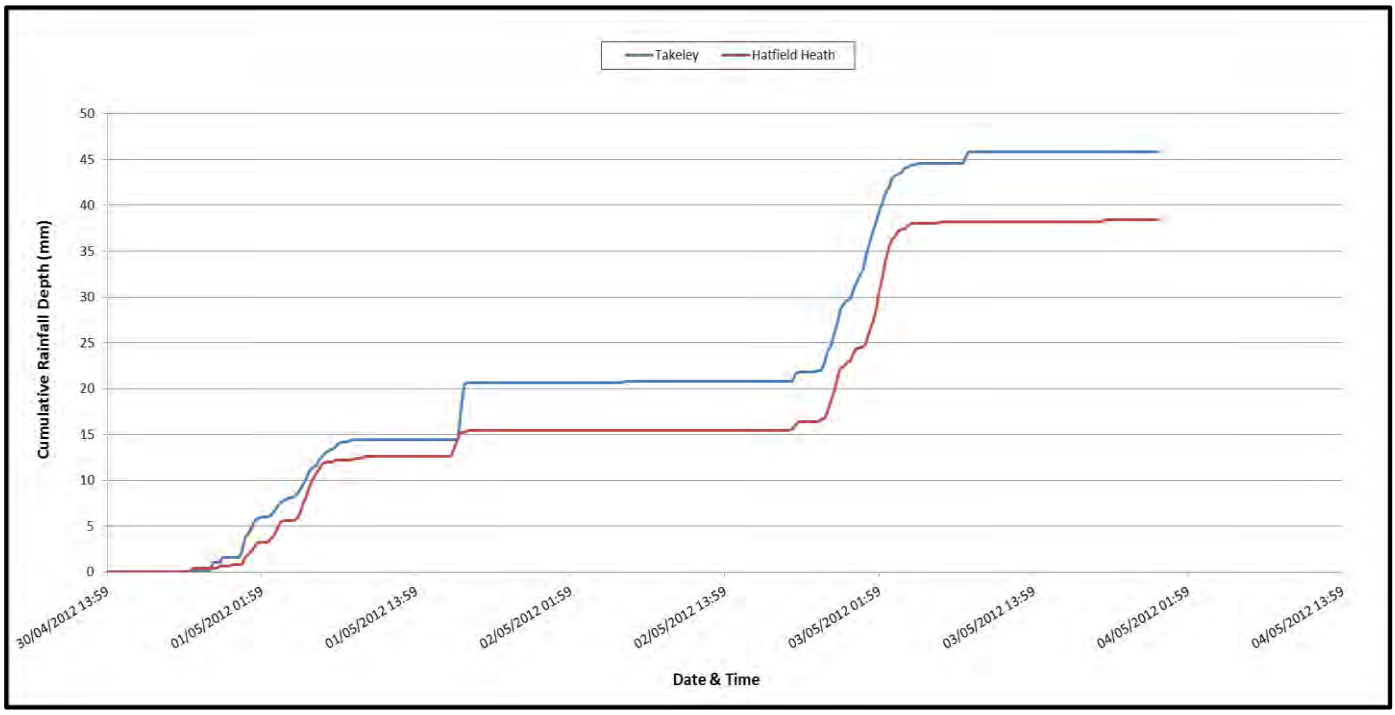


Figure 3.2 Cumulative Rainfall Plot for the 03/05/2012 Rainfall Event (Event 2)

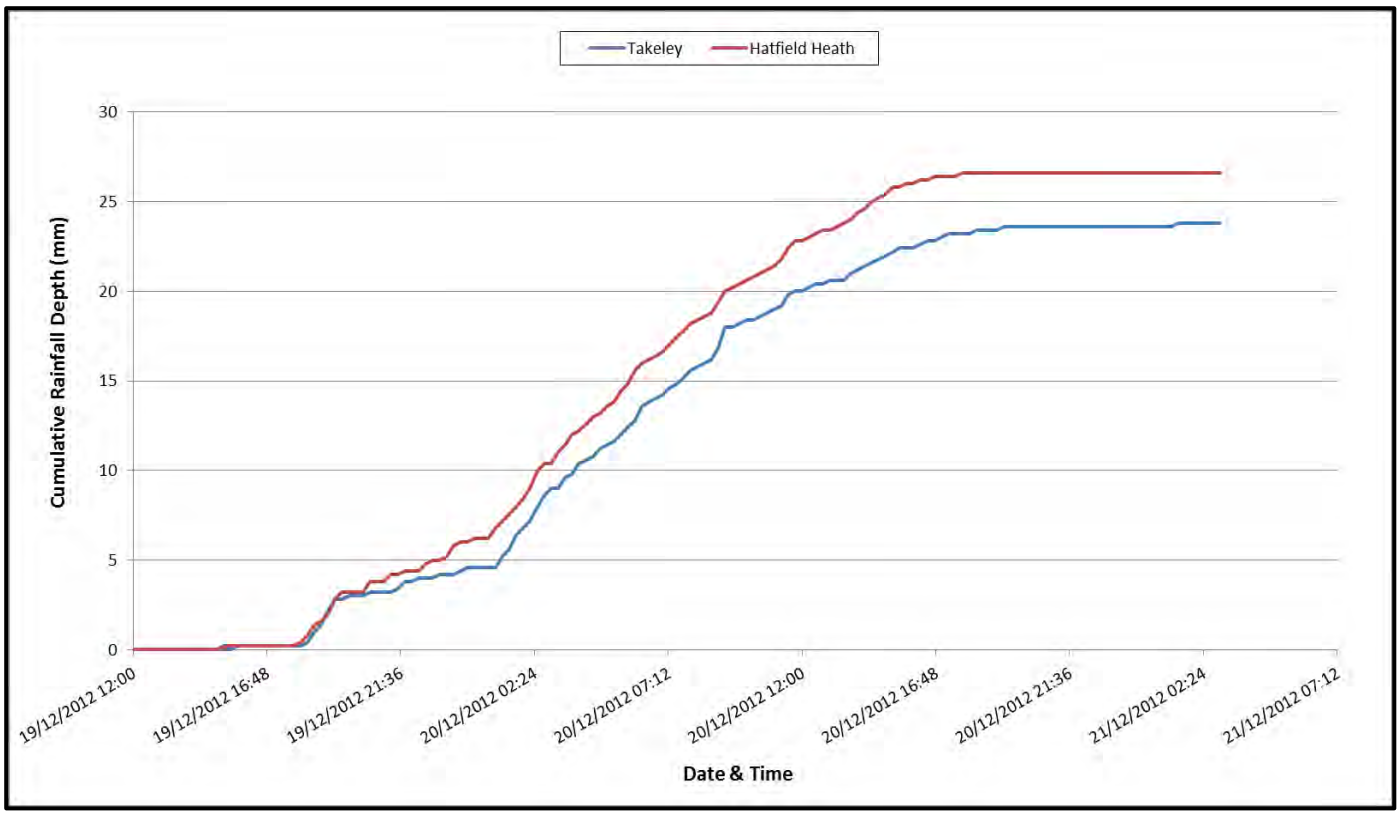


Figure 3.3 Cumulative Rainfall Plot for the 20/12/2012 Rainfall Event (Event 3)

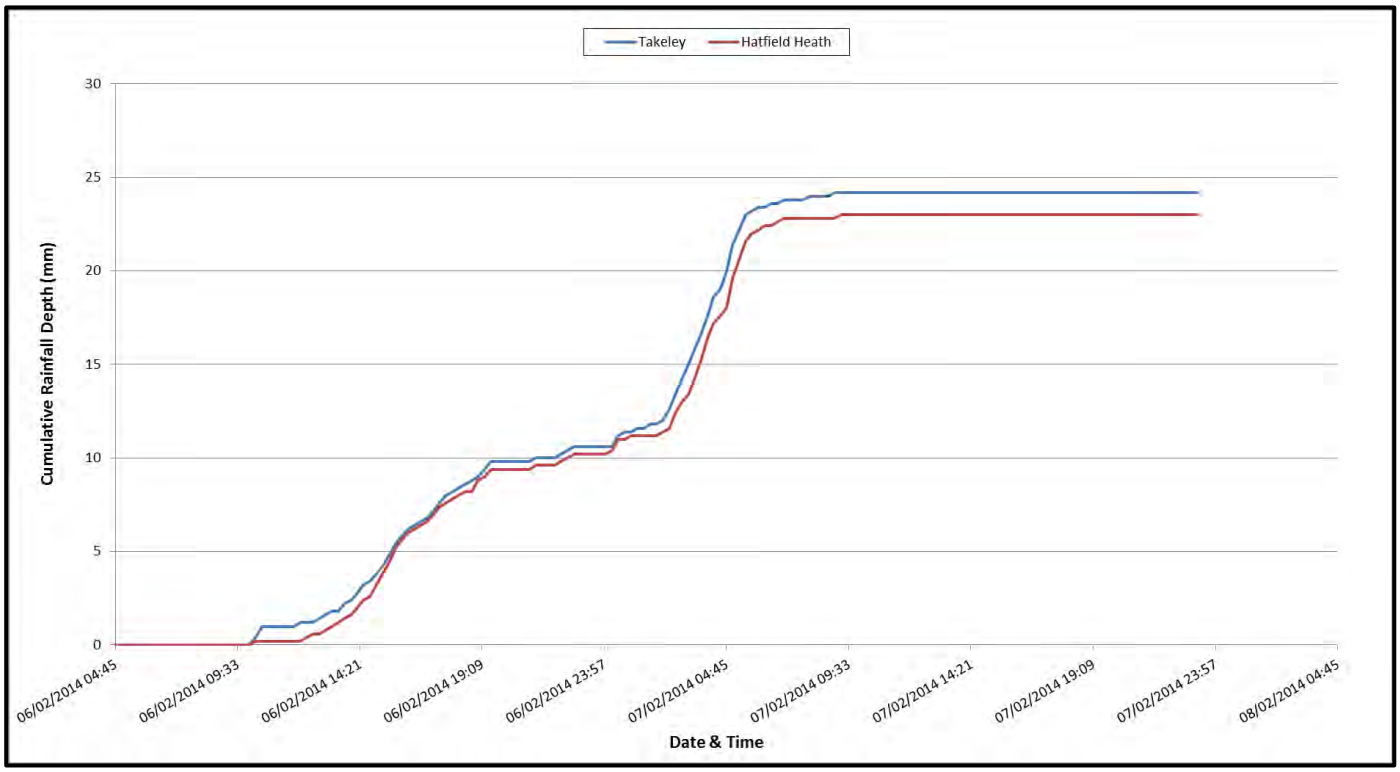


Figure 3.4 Cumulative Rainfall Plot for the 07/02/2014 Rainfall Event (Event 4)

3.2 Flow Data

To inform the design flood hydrology for the Pincey Brook Annual Maxima (AMAX) flow data, gauged 15 minute flow data, gauged daily mean flow data and spot flow gaugings were requested and received from the Environment Agency for the Pincey Brook at Sheering Hall gauging station (38026).

The AMAX flow record extends from August 1974 to February 2014. This was used in the statistical method to estimate QMED. The AMAX flow data and the spot flow gaugings are described further in Section 4.5.

15 minute flow data was received for the 18/01/2011, 03/05/2012, 20/12/2012 and 07/02/2014 rainfall events described in Section 3.1.

The rainfall data and the gauged 15 minute flows allowed us to calibrate the hydrological model for the Pincey Brook. This process is described in Section 4.3.

4. Hydrological Analysis Existing Condition

4.1 Introduction

A distributed rainfall-runoff model was used by means of the Revitalised Flood Hydrograph (ReFH) hydrological model in ISIS to generate inflow hydrographs along the model extents for a range of design storm events. The hydrological methodology used to determine the design event inflow hydrographs for each of the six inflow locations including the ReFH hydrological model calibration/verification, QMED estimation, flood frequency analysis and determination of the final design inflow hydrographs using a scaled version of the calibrated ReFH model for the Pincey Brook at each inflow location are described in the following subsections.

Although the successor of ReFH (ReFH 2) had become available when the Pincey Brook analysis was carried out, that method was not used as it was not sufficiently documented, largely untested in practice and there was no calibration tool available for it.

4.2 Gauging Station Description

There is one gauging station located on the modelled reach of the Pincey Brook, namely the Pincey Brook at Sheering Hall (Gauging Station 38026) [National Grid Reference: 549530, 212705]. The Centre for Ecology & Hydrology (CEH) website (http://nrfa.ceh.ac.uk/data/station/info/38026) notes that gauged flow and water level records at this gauging station began in January 1974. A catchment area of 51.91km^2 drains to the gauging station. The gauging station consists of a flat V weir with the following parameters taken from a topographic survey undertaken by Jacobs (Jacobs, 2015):

- Cross-slope of 1:8.68;
- Weir crest breadth of 3.93m;
- Weir crest elevation of 44.95 mAOD.

Sheering Hall gauging station (38026) records water levels and flows (based on a stage-discharge rating). A tail recorder was added to the gauging station in February 2011 to allow for the estimation of flows during non-modular flow conditions.

Maps show a bypass channel adjacent to the main river channel at the gauging station starting approximately 22 metres upstream of the weir. During a Jacobs site visit undertaken in January 2015 it was ascertained that the bypass channel at the gauging station is blocked at its upstream end and that the level of the spill into the bypass channel is at the level of the river banks (minimum spill level is 46.85 mAOD). Therefore by-passing of the gauging station structure occurs only when the river floods its banks.

4.3 Hydrological Model Calibration and Verification

The ReFH module in the ISIS software package (Version 3.7.0.233 Mode 2, based on the ReFH 1 model) was the chosen method for the estimation of the design inflow hydrographs for the Pincey Brook. Although its successor ReFH 2 had become available when the Pincey Brook analysis was carried out, the method was not sufficiently documented, largely untested in practice and there was no calibration tool available for it.

The ReFH model was calibrated to gauged flows at Sheering Hall gauging station (38026) using recorded rainfall within the Pincey Brook catchment as an input to the ReFH model. The Pincey Brook ReFH model was calibrated using the storm events with the highest observed peak water levels for recent storm events since 2011. The Pincey Brook calibration and verification events and gauged water levels are tabulated in Table 4.1 below and are shown in Figures 4.1 to 4.4. Events 2 and 3 were selected for verification as they were considered the least suitable for calibration: Event 2 has a triple peak and Event 3 has the lowest peak water

levels of the four events. Events 2 and 3 also had the greatest difference in rainfall totals between the two rain gauges in the catchment.

Table 4.1 Pincey Brook ReFH Model – Calibration and Verification Events

Event No.	Date	Peak Head Water Level	Peak Tail Water Level	Comment
	(-)	(mAOD)	(mAOD)	(-)
1	18/01/2011	46.471	N/A	Calibration
2	03/05/2012	46.597	46.609	Verification
3	20/12/2012	46.45	46.441	Verification
4	07/02/2014	46.506	46.544	Calibration

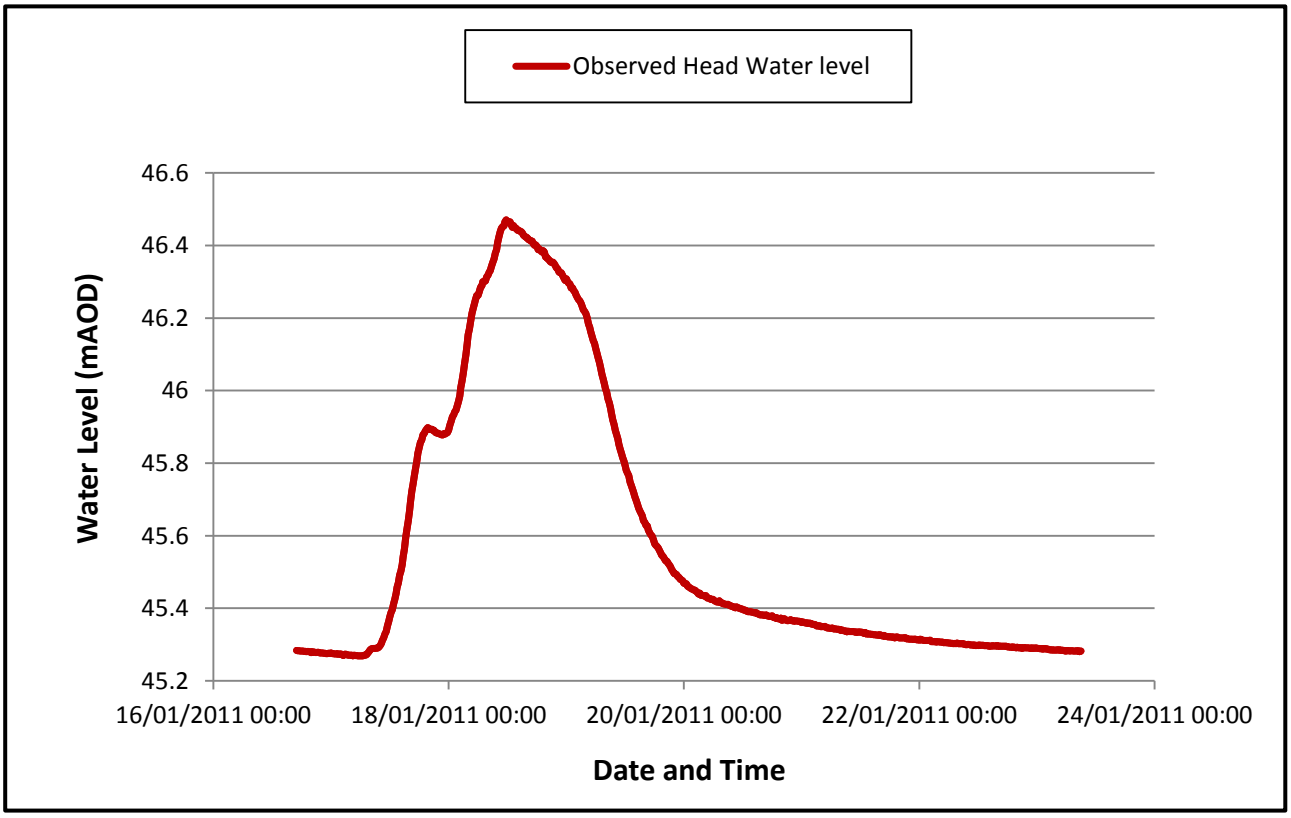


Figure 4.1 Pincey Brook Hydrological Model Calibration – Event No. 1 (18/01/2011)

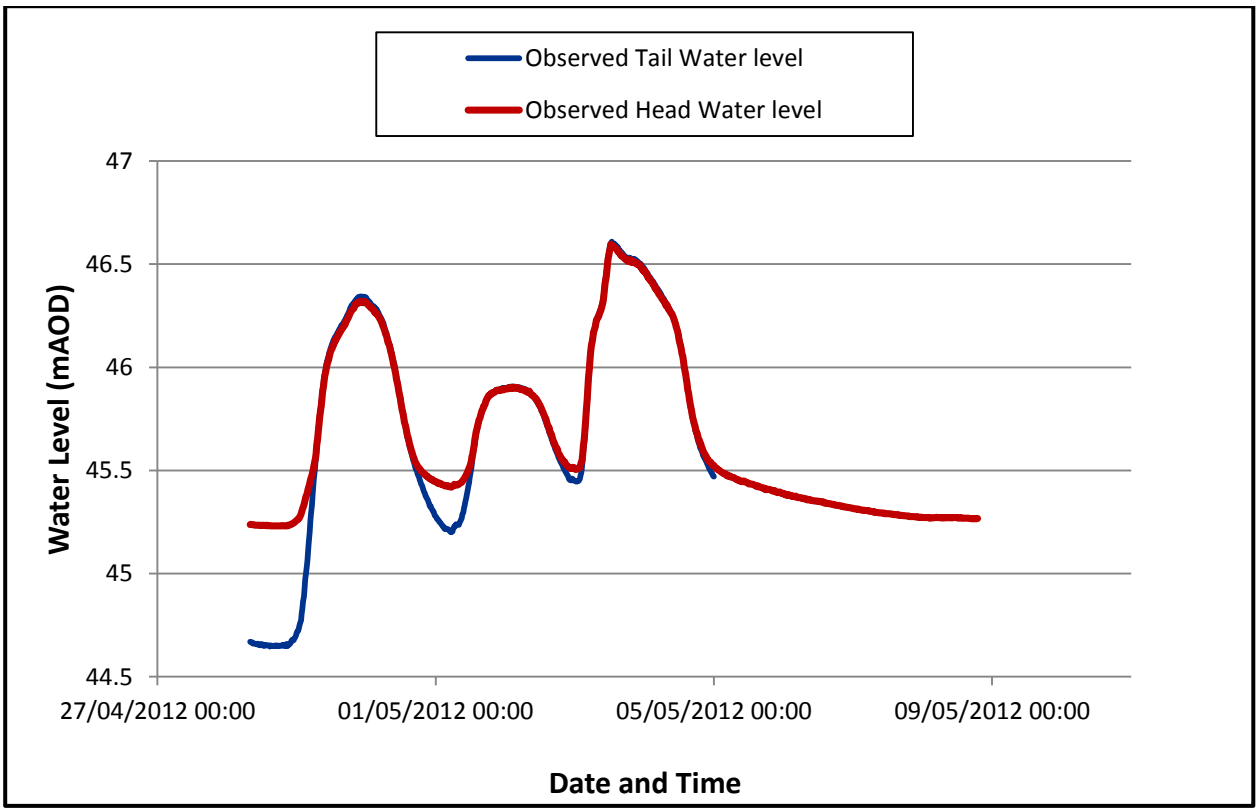


Figure 4.2 Pincey Brook Hydrological Model Verification – Event No. 2 (03/05/2012)

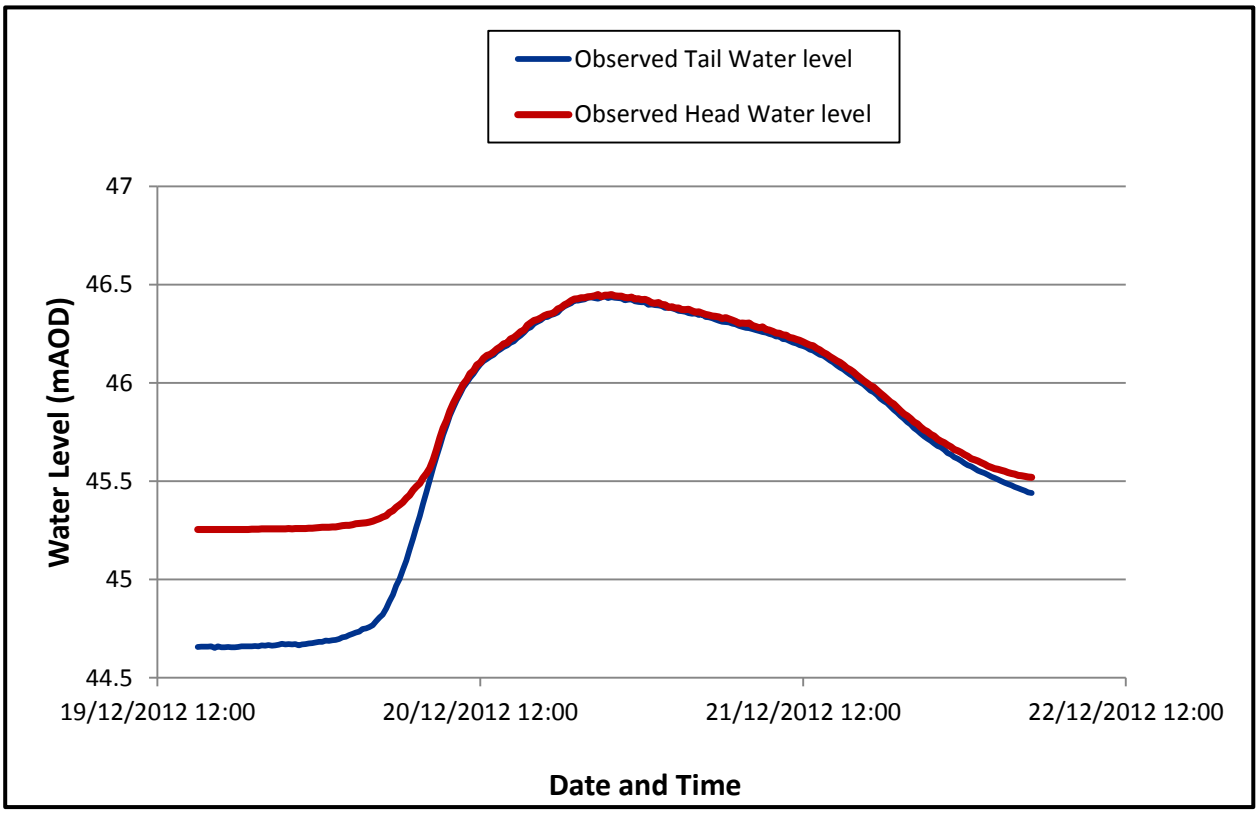


Figure 4.3 Pincey Brook Hydrological Model Verification – Event No. 3 (20/12/2012)

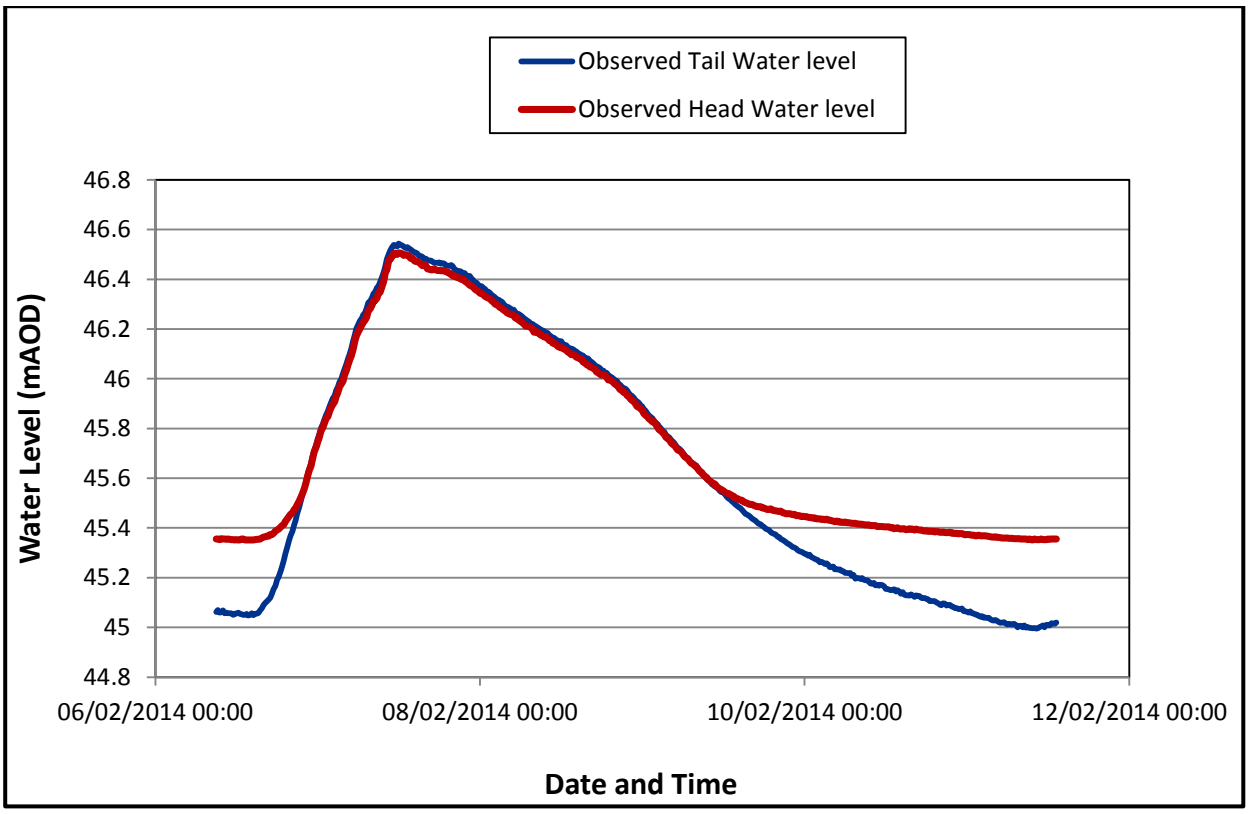


Figure 4.4 Pincey Brook Hydrological Model Calibration – Event No. 4 (07/02/2014)

As described in Section 3.1 two tipping bucket rain gauges, namely Takeley and Hatfield Heath, were chosen to estimate the average rainfall for the Pincey Brook catchment to serve as the rainfall event inputs to the ReFH model calibration and verification. The catchment average rainfall was determined using an area-weighted average of the hyetographs from the two gauges. The areas of coverage were determined using Thiessen Polygons. It was found that approximately 58% of the Pincey Brook catchment falls within the Hatfield Heath rain gauge polygon and the remaining 42% within the Takeley rain gauge polygon. Other nearby rain gauges were considered but their data was not used as their Thiessen Polygons did not cover the catchment. The area-weighted average rainfall hyetographs thus derived were used to represent the four selected calibration/verification events.

The ReFH model initial baseflow (BF_0) was set to the gauged flow at the start of each storm event. The initial soil moisture (C_{ini}) at the start of each storm event was estimated with the soil moisture model defined in the ReFH guidance using the two year record of antecedent daily rainfall data at the Hatfield Heath rain gauge. A comparison of the long term rainfall depths at Hatfield Heath with the Takeley gauge showed that they were virtually identical. The ReFH model initial soil moisture and baseflow parameters are summarised in Table 4.2 below.

Table 4.2 Pincey Brook ReFH Model Initial Parameters

Variable	Units	Calibration Events		Verification Events	
		Event 1 (18/01/2011)	Event 4 (07/02/2014)	Event 2 (03/05/2012)	Event 3 (20/12/2012)
c_{ini}	(-)	67.00	100.33	53.38	83.14
BF_0	(m^3/s)	0.54	0.91	0.33	0.40
Note: the c_{ini} and BF_0 values are user defined parameters in the calibration event ReFH models determined from gauged records.					

The initial uncalibrated Pincey Brook ReFH model was run with the average catchment rainfall, the manually estimated catchment descriptors (Table 2.4) and the initial parameters quoted in Table 4.2. This initial ReFH model run used initial estimates of the calibration parameters c_{max}, T_p, B_R and B_L based on catchment descriptors which are summarised in Table 4.3 below.

Table 4.3 Pincey Brook ReFH Model Initial Calibration Parameters

Variable	Units	Calibration Events	
		Event 1 (18/01/2011)	Event 4 (07/02/2014)
c_{max}	(-)	320.74	320.74
T_p	(hrs)	9.03	9.03
B_R	(-)	0.88	0.88
B_L	(-)	47.79	47.79

The initial ReFH modelled flows for the two calibration events were compared against the observed flows at Sheering Hall which showed an inadequate fit. Therefore, the values for c_{max} and B_R were amended iteratively to improve the fit of the ReFH model to the gauged flows. The calibration parameters T_p and B_L were appropriate and were not changed. Table 4.4 below summarises the final calibration parameters that resulted in a good fit between observed flows and the ReFH modelled flows for Calibration Event 1 and Calibration Event 4. Figures 4.5 and 4.6 show the comparison between the calibrated ReFH model flows and the gauged flows for the two calibration events.

Table 4.4 Pincey Brook ReFH Model Final Calibration Parameters

Calibration Parameter	Units	Calibration Events	
		Event 1 (18/01/2011)	Event 4 (07/02/2014)
c_{max}	(-)	278.00	423.00
T_p	(hrs)	9.03	9.03
B_R	(-)	1.20	1.20
B_L	(-)	47.79	47.79

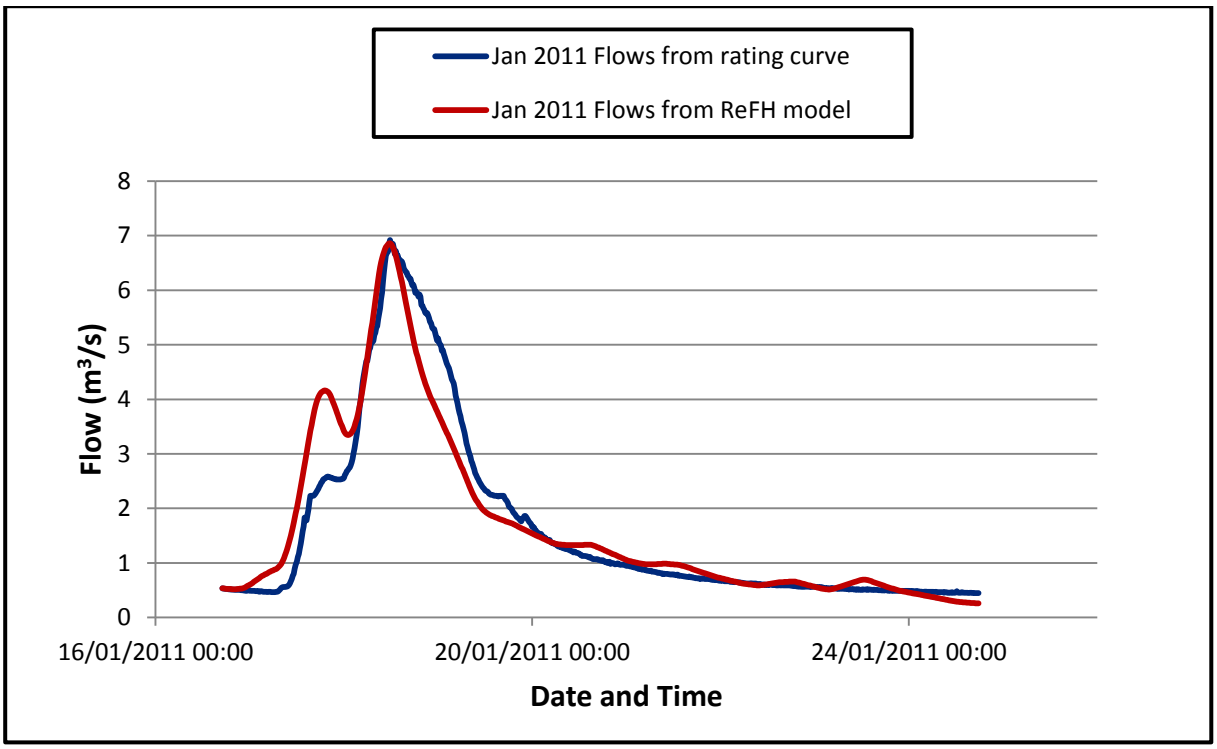


Figure 4.5 ReFH Modelled Flows Versus Gauged Flows for Calibration Event 1 (18/01/2011)

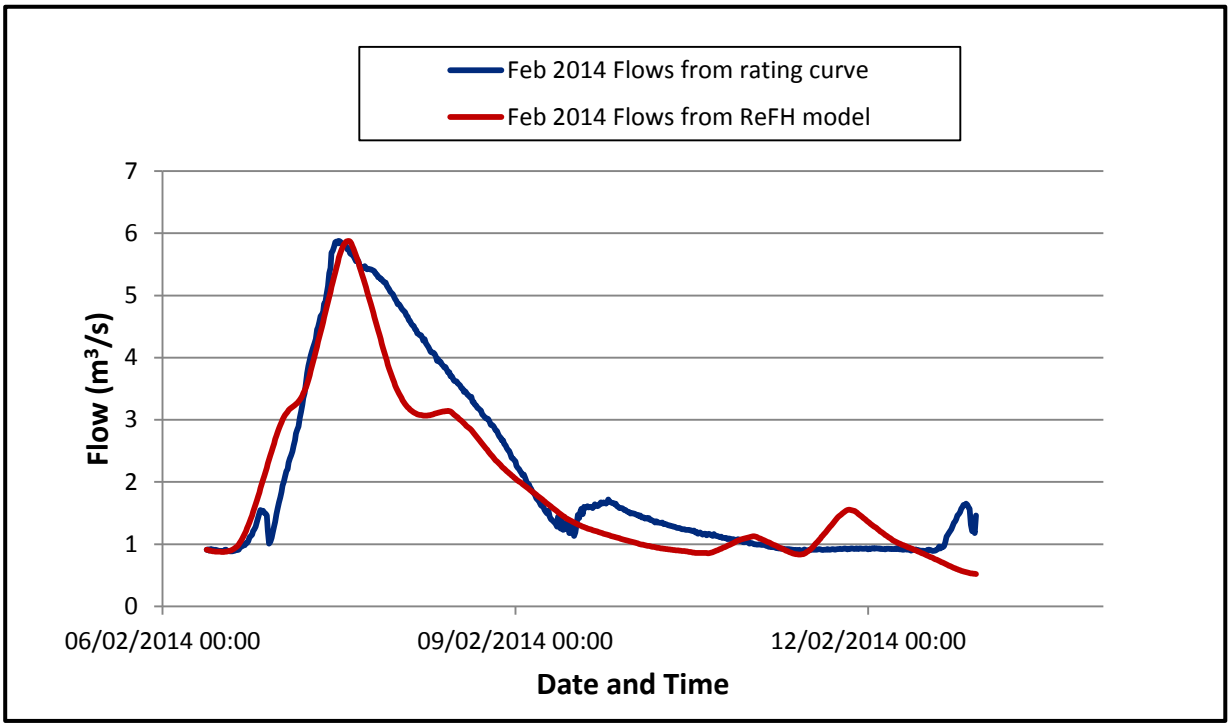


Figure 4.6 ReFH Modelled Flows Versus Gauged Flows for Calibration Event 4 (07/02/2014)

The $c_{max,}$ T_p, B_L and B_R values determined for the two calibration events [Event 1 (18/01/2011) and Event 4 (07/02/2014)] were then applied to the two verification events [Event 2 (03/05/2012) and Event 3 (20/12/2012)]. It was found that the calibration parameters for Calibration Event 1 produced the best fit between the ReFH modelled flows and the gauged flows for Verification Event 3 (See Figure 4.8). The parameters for both calibration events produced a poor fit for Verification Event 2 (See Figure 4.7) and it was considered that the peak flow for Event 4 (November 2014) may have been an underestimate. Therefore the calibration parameter values for Calibration Event 1 were adopted for the design event model simulations, appreciating that this gives the higher (conservative) flow estimates.

The adjustment factors derived from the ratio between the initial and final calibration parameters for Calibration Event 1 are applied to the calibration parameters c_{max} and B_R for the ReFH models at the six inflow locations along the Pincey Brook model extent (the other calibration parameters T_p and B_L remained unchanged). The application of consistent calibration parameter adjustment factors for each inflow location ReFH model ensures consistency in the hydrology throughout the Pincey Brook river reach of interest, whilst allowing differences between subcatchments to exist based on differing catchment characteristics. The calibration parameter adjustment factors are presented in Table 4.5 below.

Table 4.5 Pincey Brook ReFH Model Calibration Parameter Adjustment Factors

Calibration Parameter	Adjustment Factor
	(-)
c_{max}	0.87
T_p	1.00
B_R	1.36
B_L	1.00

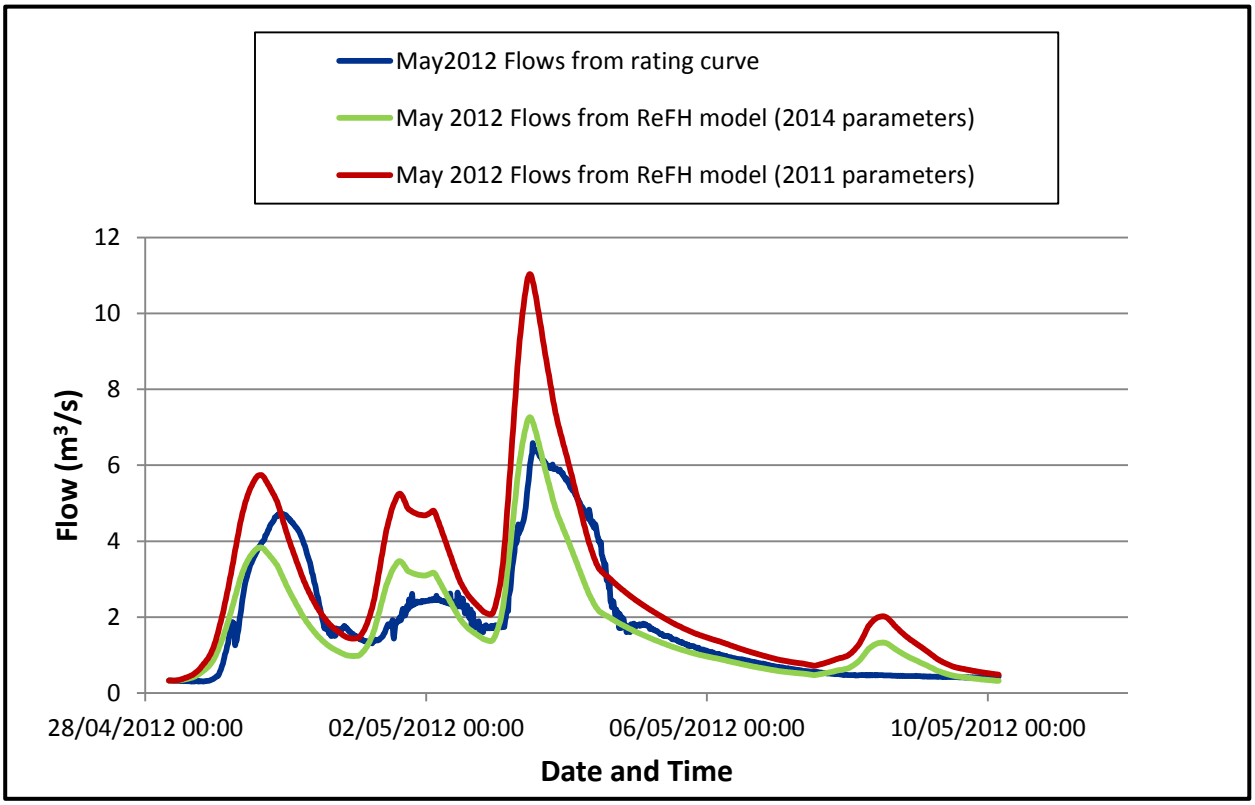


Figure 4.7 ReFH Modelled Flows Versus Gauged Flows for Verification Event 2 (03/05/2012)

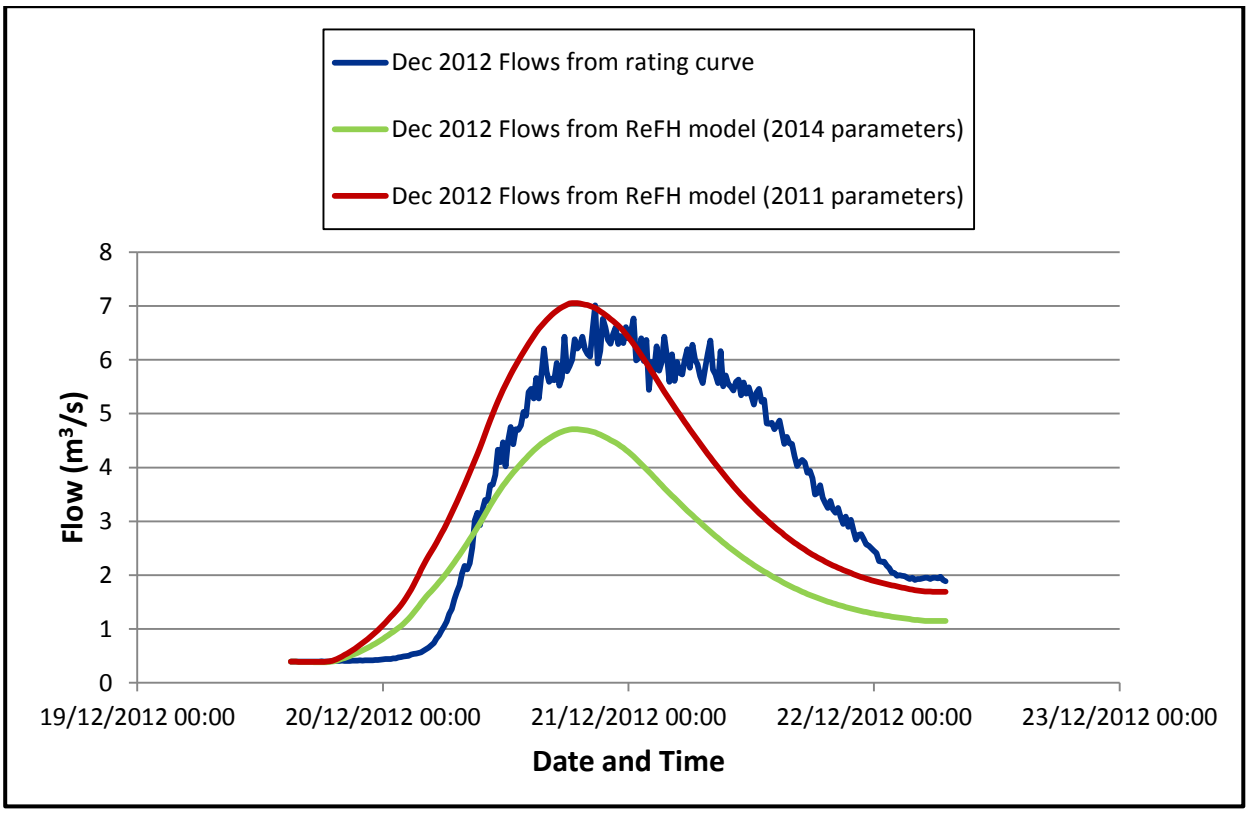


Figure 4.8 ReFH Modelled Flows Versus Gauged Flows for Verification Event 3 (20/12/2012)

4.4 (Unscaled) Calibrated ReFH Design Event Model

The calibrated ReFH model from Section 4.3 was used to produce design event hydrographs for a range of return periods at the gauging station. The design event peak flows are presented in Table 4.6 below.

Table 4.6 ReFH Design Event Unscaled Peak Flows at Sheering Hall Gauging Station

Return Period	Unscaled ReFH Peak Flow Estimate (m^3/s)
2	9.2
5	12.2
20	17.0
100	24.5
1000	45.4

In the next two sections the FEH statistical method was employed to produce alternative peak flow estimates. The two sets of estimates are compared in Table 4.9 in Section 4.7.

4.5 QMED Estimation from Annual Maxima

The National River Flow Archive (NRFA) website (dataset version v.4.1 – May 2016) at http://nrfa.ceh.ac.uk/data/station/peakflow/38026 provides 41 Annual Maxima (AMAX) flow recordings, from hydrometric year 1973 to 2013. The Environment Agency provided the peak flow data from 1982 onwards which had recently been re-processed to correct for non-modularity described in Section 4.2. AMAX flows for the years

preceding 1982 were not corrected and hence they have been discarded. An additional AMAX flow recording for hydrometric year 2014 was also provided in May 2016 and this was added to the AMAX flow series. As a consequence the AMAX flow record comprises of 33 AMAX flow recordings. The AMAX flow series is presented in Table D.1 in Annex D. A plot of the AMAX flow series is presented in Figure 4.9 below.

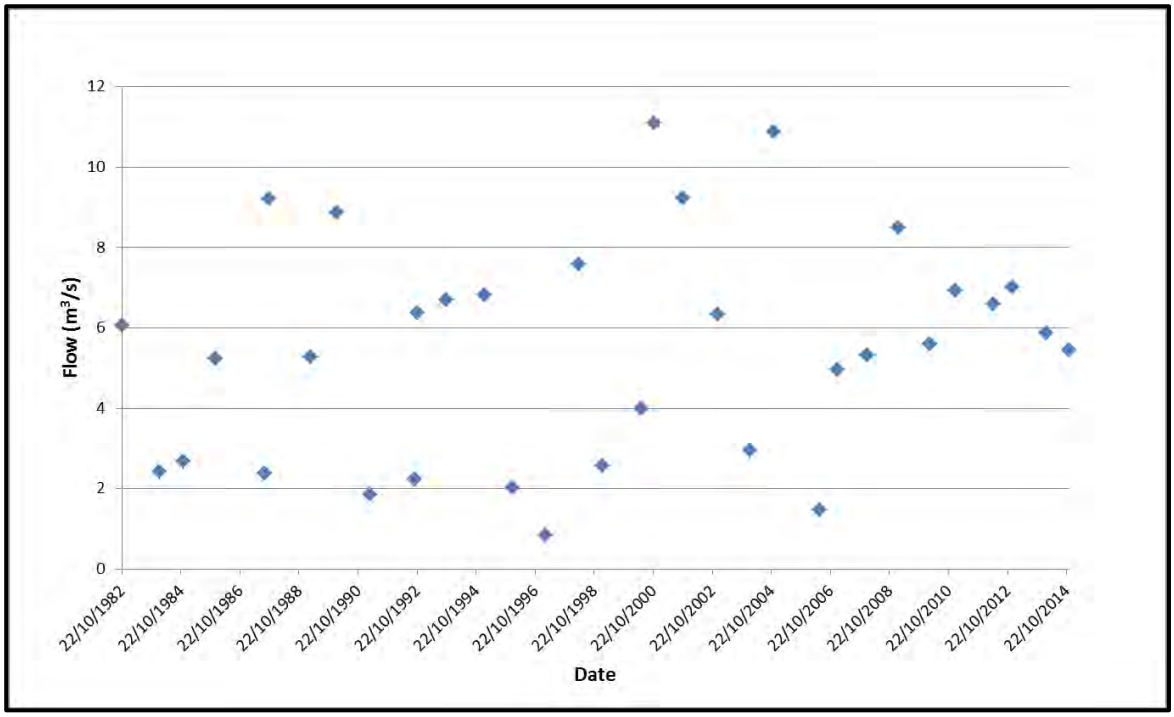


Figure 4.9 Sheering Hall Gauging Station (38026) AMAX Flows

Although the NRFA website indicates that the Sheering Hall gauging station is not suitable for QMED estimation, it was found that recent spot flow gaugings gave sufficient confidence in the data to derive a good estimate of QMED. To illustrate this Figure 4.10 below shows a plot of stage versus discharge with the recorded spot flow gaugings and AMAX flows. The spot flow gaugings show little scatter and the highest spot flow gauging (4.51 m^3/s) is about 80% of the estimate of QMED based on the AMAX flow series (5.6 m^3/s, discussed below). The AMAX flow data (estimated from an EA stage-discharge rating and corrected for drowning of the weir) aligns well with the spot flow gaugings and hence QMED was estimated from the gauged AMAX flow record to inform the flood hydrology for Pincey Brook.

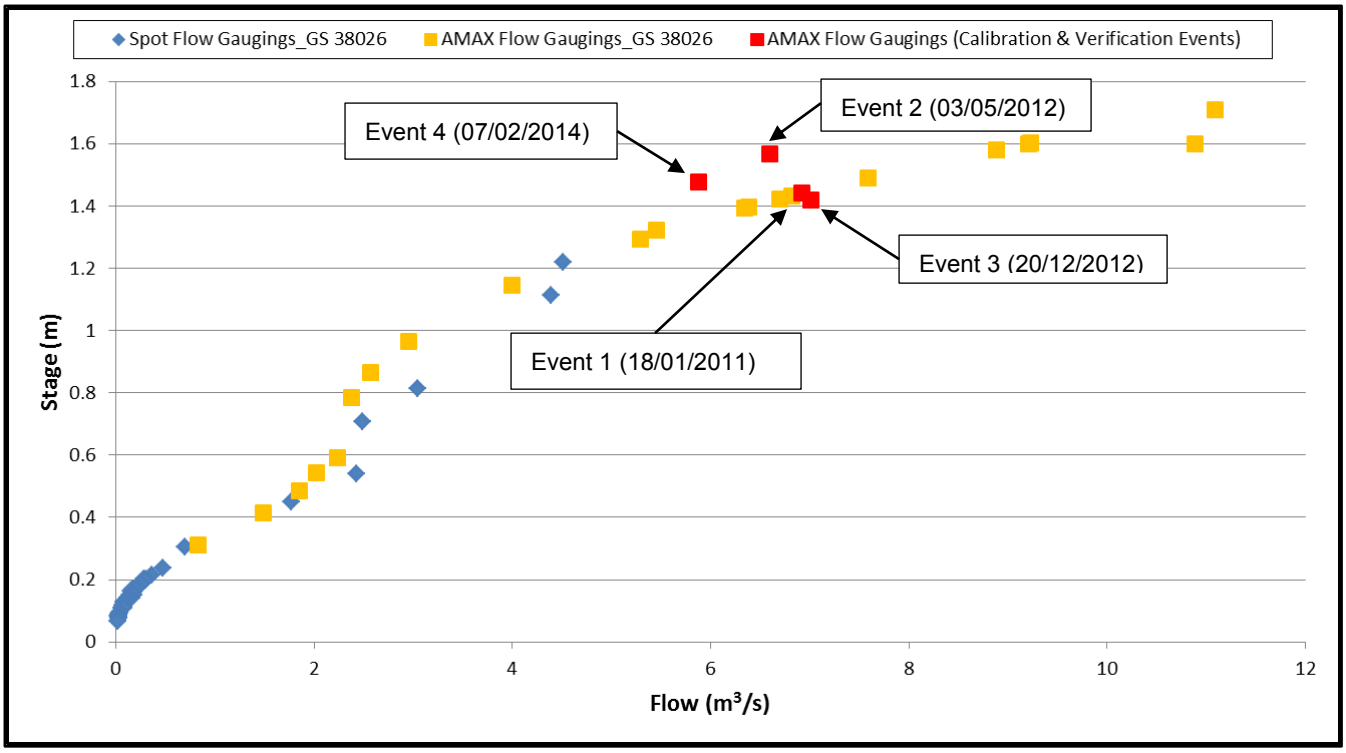


Figure 4.10 Sheering Hall Gauging Station (38026) Stage – Discharge Relationship

As recommended by the Flood Estimation Handbook Volume 3 (Section 2.3, page 6) for gauging stations comprising 14 years or more of record AMAX flow data, QMED for Pincey Brook at Sheering Hall gauging station (38026) was estimated from the AMAX flow series (See Table D.1 in Annex D) by taking the median of the AMAX flow series. This gives a gauged QMED estimate of **5.6 m^3/s**. The QMED estimate is used to estimate the statistical peak flows for various design storm return periods with the application of suitable growth factors determined through flood frequency analysis. The flood frequency analysis undertaken at the gauging station (38026) is described in Section 4.6.

4.6 Flood Frequency Analysis

Given that Sheering Hall gauging station has 33 years of usable AMAX flow data statistical peak flow estimates could only be reliably estimated up to approximately the 1 in 16 year return period storm event (i.e. up to approximately half the gauged AMAX flow record), even if the AMAX flows were reliable. As it is, the AMAX series is not considered reliable above QMED. Therefore, pooling group analysis was undertaken in accordance with the guidance set out in the Flood Estimation Handbook (Centre for Ecology & Hydrology, 1999) and updated in 2008 (Kjeldsen, T.R., 2008). The software package used to undertake pooling group analysis was WINFAP (Version 3.0.003) with the WINFAP gauging station database (Version 3.3.4 of August 2014) found on the NRFA website at http://nrfa.ceh.ac.uk/winfap-feh-files. The audit trail documenting the pooling analysis findings can be found in Annex E.

The catchment to the gauging station was used to generate the flood frequency curve for the Pincey Brook. For the unnamed tributary from The Mores woodland the flood frequency curve from the Pincey Brook was adopted as the catchment is too small to yield sufficient pooling stations that are hydrologically similar.

The pooling group does not include the Sheering Hall gauging station itself as it is deemed unsuitable for pooling given that the rating cannot be validated for high flows due to the lack of high flow spot gaugings.

It was found that the best fitting statistical distribution for the Pincey Brook was the Generalised Logistic. The final growth factors and associated statistical peak flow estimates up to the 1000 year return period are presented in Table 4.7 below. Applying the growth factors outlined in Table 4.7 below to the QMED estimate of 5.6 m^3/s determined in Section 4.5 results in the statistical peak flow estimates.

Table 4.7 Pooling Group Growth Factors & Statistical Peak Flow Estimates

Return Period	Growth Factor	Statistical Peak Flow Estimate
	(-)	(m^3/s)
2	1.00	5.6
5	1.41	7.9
20	1.94	10.9
100	2.59	14.5
1000	3.68	20.6

4.7 Scaling of the ReFH Design Event Hydrographs

Chapter 4 this far has described the calibration of a ReFH model for the Pincey Brook, and the resulting design event model (See Sections 4.3 and 4.4) and the determination of statistical design event peak inflow estimates at Sheering Hall gauging station (See Sections 4.5 and 4.6). In order to determine the design flood hydrographs at the gauging station a scaling procedure was undertaken to scale the ReFH design hydrographs to the statistical peak flow estimates (according to the 'hybrid method' as described in the FEH Supplementary Report No. 1 [Centre for Ecology & Hydrology, 2007]). This scaling is carried out by varying the initial soil moisture content (c_{ini}) and the initial soil moisture correction factor (α_T) until the ReFH hydrographs match the statistical peak flows.

In brief the procedure employed to determine the parameters c_{ini} and α_T and facilitate hydrograph scaling to the statistical peak flows at Sheering Hall gauging station was undertaken as follows:

(1) Firstly the critical storm duration for the Pincey Brook was estimated using the calibrated ReFH model at the gauging station. The critical storm duration was determined for the 100 year return period design event as this is considered the target design event for the M11 Junction 7A road scheme. The storm duration was adjusted until the flood hydrograph yielding the highest peak flow was identified. The critical storm duration was determined to be 24 hours, which compares very well with the observed storms used in the calibration/verification in Section 4.3. This critical storm duration was adopted for all modelled design events (2, 20, 100 and 1000 year return periods) ensuring consistency in the design flood hydrology.

(2) The calibrated ReFH model at Sheering Hall gauging station was run for the 5 year return period design event (with a critical storm duration of 24 hours) as this is the baseline from which the c_{ini} and the various α_T parameters are determined. In order to fit the ReFH flood hydrograph for the 5 year return period design event to the corresponding statistical peak flow c_{ini} was adjusted until the ReFH design hydrograph peak and statistical peak flows match. The α_T correction factor is set at one for this step.

(3) In order to determine the α_T correction factors that allow the ReFH design hydrographs for 2, 20, 100 and 1000 year return period design events to be determined the c_{ini} from step (2) was used and the α_T correction factor adjusted until the ReFH design hydrograph peak and statistical peak flows match yielding the α_T correction factors for the aforementioned design events at Sheering Hall gauging station. It should be noted that the c_{ini} is a single value applicable to all design events and remains unadjusted from the value determined for the 5 year return period design event baseline.

(4) A departure from the FEH flood frequency analysis methodology was required to determine a best estimate of the 1000 year return period peak flow. The 1000 year return period peak flow could not be estimated through pooling group analysis as statistical estimates are considered less reliable for such a high return period storm event given the relative short lengths of historic gauged AMAX flow data across the UK. Pooling has a tendency to produce a low estimate for the 1000 year peak which is thought to be an underestimate. Therefore, in accordance with the method described in the EA FEH Guidance Note (EA, 2015) the 1000 year peak flow was determined using ReFH with the model parameters (i.e. c_{ini}, α_T) from the 100 year design event applied to the 1000 year return period flood. This gave a considerably higher 1000 year peak flow at the gauging station than the statistical estimate, and this higher estimate was adopted for the hydraulic modelling.

The resulting ReFH flood hydrograph scaling parameters c_{ini} and α_T determined by the procedure described above at Sheering Hall gauging station are summarised in Table 4.8 below.

Table 4.8 ReFH Flood Hydrograph Scaling Parameters at Sheering Hall Gauging Station (38026)

Variable	Units	Design Event Return Period (years)				
		2	5	20	100	1000
c_{ini}	(-)	71.9				
α_T	(-)	0.97	1.00	0.87	0.61	0.61 (adopted from 100yr)

A comparison of the final peak flows from the statistical method, ReFH (unscaled) and the finally adopted peak flow estimates at the gauging station are shown in Table 4.9 below.

Table 4.9 Comparison of statistical, ReFH (Unscaled) and ReFH (Scaled) Peak Flows at Sheering Hall Gauging Station

Return Period	Statistical Peak Flow Estimate	Unscaled ReFH Peak Flow Estimate	Scaled ReFH Peak Flow Estimate (adopted)
	(m^3/s)	(m^3/s)	(m^3/s)
2	5.6	9.2	5.6
5	7.9	12.2	7.9
20	10.9	17.0	10.9
100	14.5	24.5	14.5
1000	20.6	45.4	33.4

For comparison ReFH model inflows for the Pincey Brook developed by Halcrow in a previous study entitled "Stort Modelling and Mapping Flood Risk Study" (Halcrow, 2010) are presented in Table 4.10. Refer to the M11 Junction 7A hydraulic modelling report for the Pincey Brook (Appendix to the FRA) which describes this Halcrow report. The table shows that previously the flows in the Pincey Brook were overestimated. This was because no allowance was made for non-modular flows at the gauging station. In January 2011 a tail water level gauge was installed and recently flows at this gauge have been re-estimated using a non-modular correction. The comparison of the revised AMAX flows and the spot flow gaugings in Figure 4.10 shows that the reworked

AMAX flows fit the spot gaugings well in the overlapping range, indicating that the non-modularity correction has improved the flow estimates.

Table 4.10 Pincey Brook Peak Inflows from "Stort Modelling and Mapping Flood Risk Study" by Halcrow

2yr	5yr	20yr	100yr	1000yr
(m^3/s)				
11.08	15.78	21.56	28.34	39.11

4.8 Distribution of the ReFH Model

To determine the ReFH design hydrographs for the 2, 5, 20, 100 and 1000 year return period design events at the six inflow locations along the Pincey Brook the scaling parameters in Table 4.8 were used to scale from the 5 year return period baseline ReFH design hydrographs at each inflow location to the 2, 20, 100 and 1000 year return period design events. The resulting flood hydrographs at the six inflow locations along the Pincey Brook are presented in Figures 4.11 to 4.16 below. The peak flows associated with these hydrographs are summarised in Table 4.11 below in addition to the 100 year return period event plus 35% uplift (higher central allowance) and 70% uplift (upper allowance) for climate change in accordance with climate change guidance from the Environment Agency (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances). These design hydrographs constitute the inflows into the hydraulic model for the Pincey Brook thereby enabling design hydrographs to be routed through the hydraulic model and assess the impact (if any) to and from the proposed M11 Junction 7A development on fluvial flood risk.

Table 4.11 ReFH Flood Hydrograph Peak Inflows (Existing Condition)

Inflow Location	Easting	Northing	Peak Inflows						
			2yr	5yr	20yr	100yr	100yr (+35% CC)	100yr (+70% CC)	1000yr
	(m)	(m)	(m^3/s)						
PB1	550577	212953	5.56	7.84	10.79	14.41	19.45	24.49	33.12
PB2	550098	212846	0.24	0.34	0.47	0.63	0.84	1.06	1.45
PB3	549392	212177	0.10	0.14	0.19	0.25	0.34	0.43	0.58
Lateral 1	s. 549922 e. 549186	s. 212832 e. 212645	0.15	0.21	0.29	0.39	0.53	0.67	0.91
PB4	549078	212629	0.05	0.07	0.10	0.13	0.18	0.23	0.31
Lateral 2	s. 548988 e. 548112	s. 212557 e. 212796	0.13	0.18	0.25	0.33	0.45	0.56	0.77
s. = Start , e. = End, CC = Climate Change									

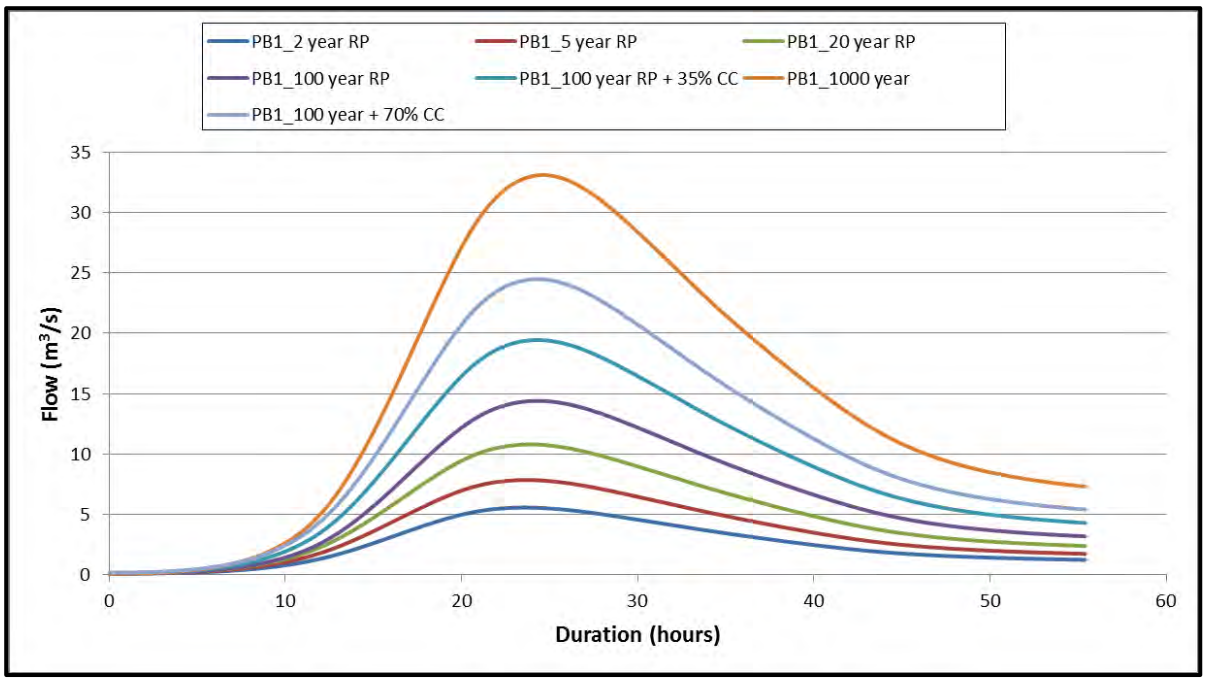


Figure 4.11 Pincey Brook ReFH Design Hydrographs for Inflow Location PB1

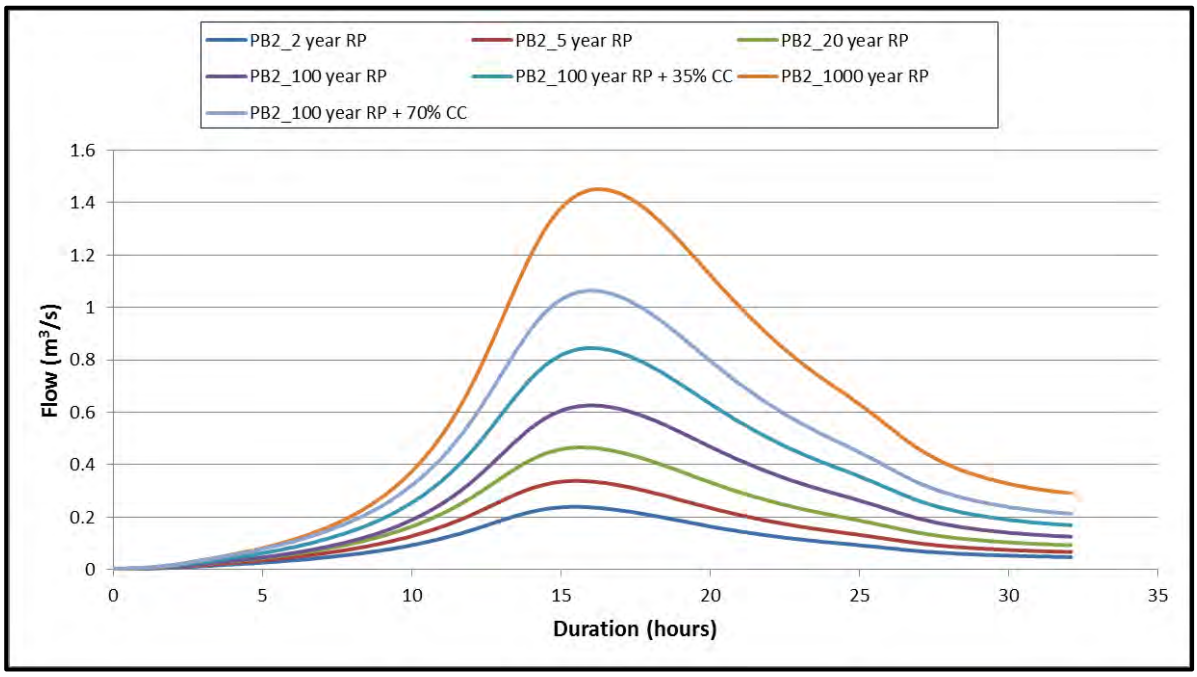


Figure 4.12 Pincey Brook ReFH Design Hydrographs for Inflow Location PB2

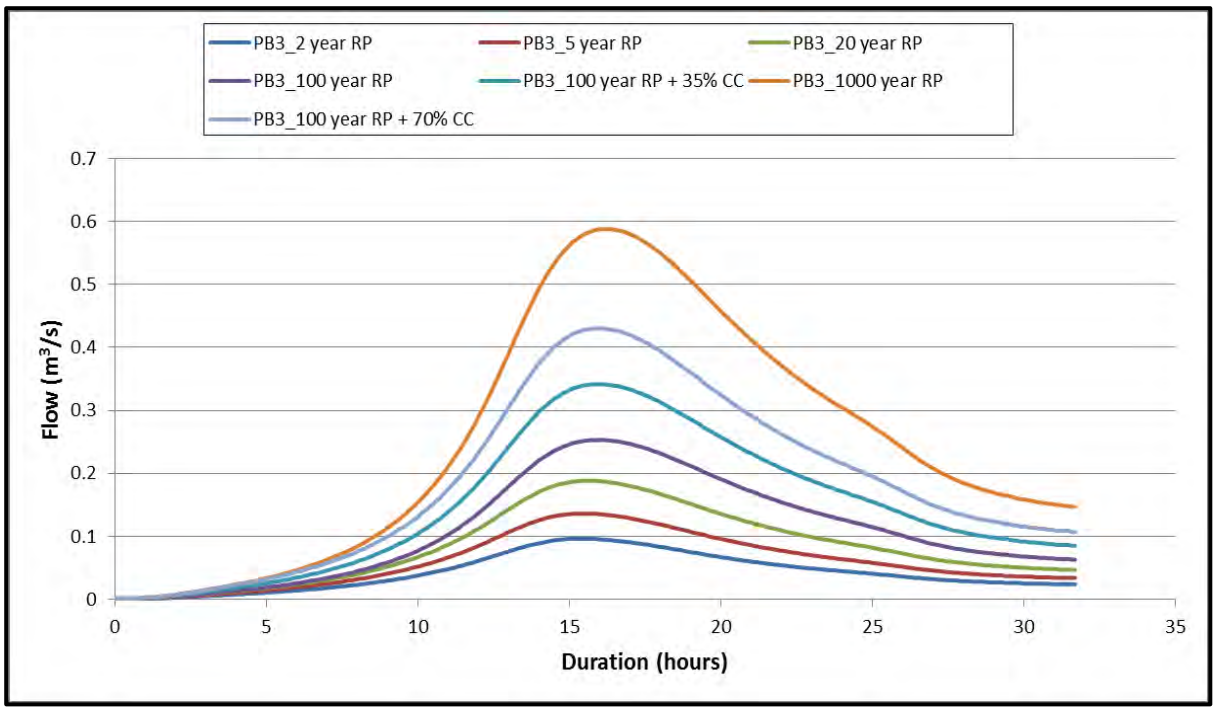


Figure 4.13 Pincey Brook ReFH Design Hydrographs for Inflow Location PB3

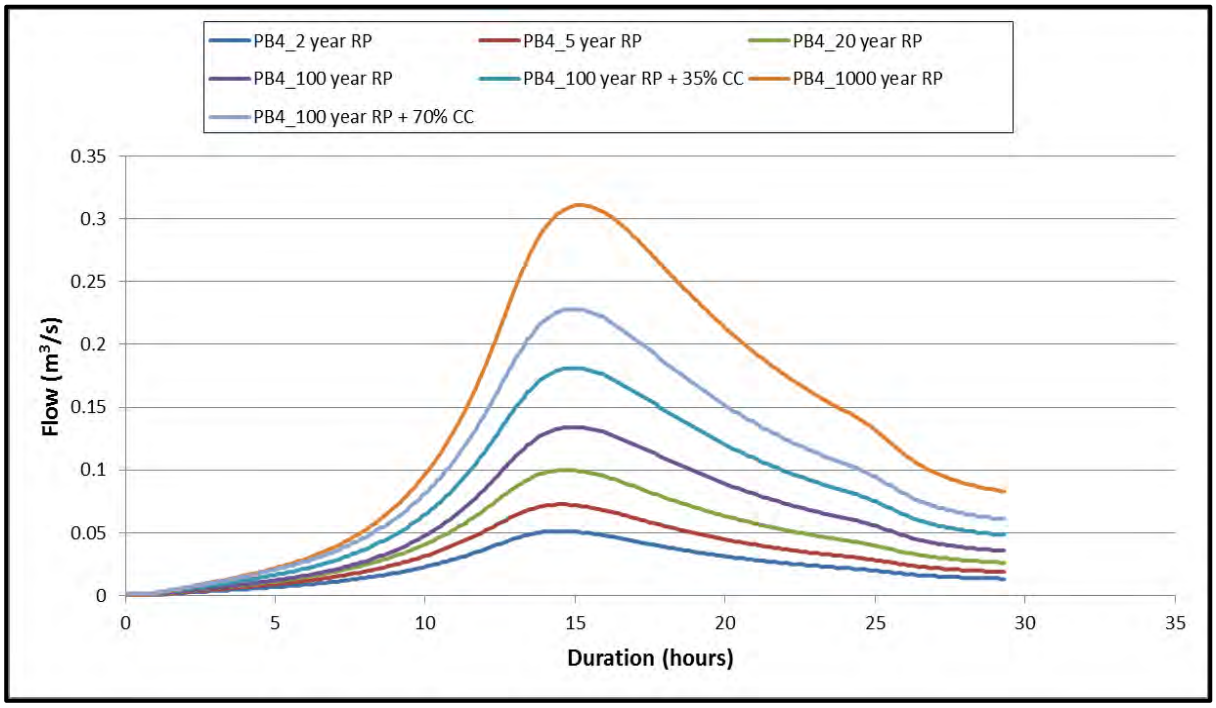


Figure 4.14 Pincey Brook ReFH Design Hydrographs for Inflow Location PB4

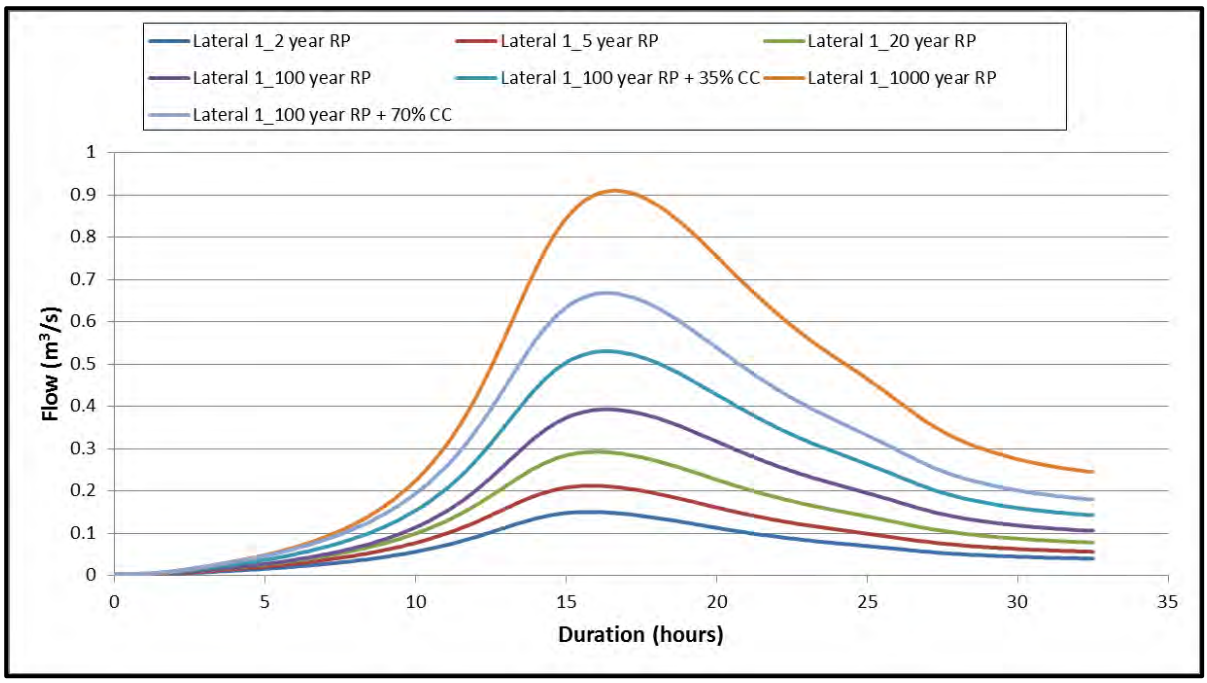


Figure 4.15 Pincey Brook ReFH Design Hydrographs for Inflow Location "Lateral 1"

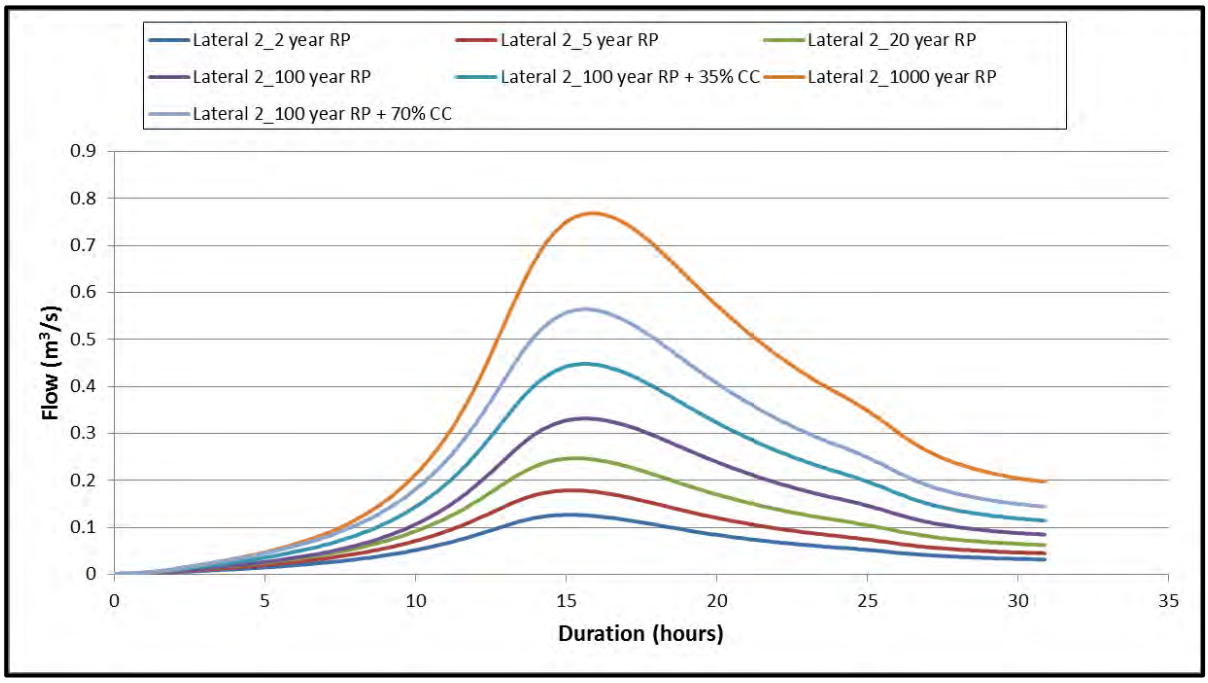


Figure 4.16 Pincey Brook ReFH Design Hydrographs for Inflow Location "Lateral 2"

5. Hydrological Analysis With-Scheme Condition

A plan of the Pincey Brook with the proposed M11 Junction 7A road scheme superimposed (excluding the southern extent of the Gilden Way part of the scheme) is presented in Annex B. The inflow locations along the Pincey Brook are the same for the proposed road scheme as for the Pincey Brook without the road scheme described in Chapter 4. The only impacts of the proposed road scheme on the Pincey Brook catchment hydrology are as follows:

(1) As shown in the proposed case plan in Annex B the B183 road alignment will provide a barrier to natural catchment runoff presently draining towards the Pincey Brook reach represented by inflow extent “Lateral 2”. The small triangular catchment area represented by the hatched polygon in the plan will be diverted by a cut-off ditch into the catchment area discharging to inflow location PB4 (upstream of Lateral 2) to mitigate surface water flooding of the proposed road scheme. Hence, the catchment area draining to “Lateral 2” is decreased while the catchment area to PB4 is increased as a consequence of the proposed road scheme.

(2) The proposed attenuation ponds that are to discharge to the Pincey Brook are shown in blue on the plan in Annex B. The discharge rates from the attenuation ponds will be restricted based on reduced existing discharge rates and/or greenfield runoff rates, and are insignificantly small compared to the flows in the Pincey Brook from a 52 km^2 catchment. Therefore no specific allowance was made for the proposed road runoff in the with-scheme inflow hydrographs.

Presented in Table 5.1 is a summary of the with-scheme ReFH peak inflows.

Table 5.1 ReFH With-Scheme Flood Hydrograph Peak Inflows

Inflow Location	Easting	Northing	Peak Inflows						
			2yr	5yr	20yr	100yr	100yr (+35% CC)	100yr (+70% CC)	1000yr
	(m)	(m)	(m^3/s)						
PB1	550577	212953	5.56	7.84	10.79	14.41	19.45	24.49	33.12
PB2	550098	212846	0.24	0.34	0.47	0.63	0.84	1.06	1.45
PB3	549392	212177	0.10	0.14	0.19	0.25	0.34	0.43	0.59
Lateral 1	s. 549922 e. 549186	s. 212832 e. 212645	0.15	0.21	0.29	0.39	0.53	0.67	0.91
PB4	549078	212629	0.06	0.09	0.12	0.16	0.22	0.27	0.37
Lateral 2	s. 548988 e. 548112	s. 212557 e. 212796	0.12	0.17	0.23	0.31	0.41	0.52	0.71
s. = Start, e. = End, CC = Climate Change									

6. Hydraulic Model Calibration

For the hydraulic model calibration the same four events were used as for the hydrological calibration discussed in Section 4.3.

The procedure followed to calibrate the hydraulic model and the outputs of the hydraulic model calibration are described in Section 2.5 of the Hydraulic Modelling Report which is an Appendix to the FRA.

7. Conclusions

Hydrological analysis was undertaken to develop inflow hydrographs to apply to the hydraulic modelling of the Pincey Brook and one unnamed tributary, to inform the M11 Junction 7A Flood Risk Assessment.

In order to determine accurate peak inflow estimates and hydrographs for the Pincey Brook the FEH statistical method and ReFH were used as part of a 'hybrid method' as described in the FEH Supplementary Report No. 1 (Centre for Ecology & Hydrology, 2007). The ReFH method involved the calibration of a ReFH model (available in the ISIS software package) at Sheering Hall gauging station to observed flow data using corresponding recorded rainfall data as an input. When applied to the design events it was found that the calibrated ReFH model gave higher flow estimates than the FEH statistical method. However, the FEH statistical method uses the gauged AMAX flow series at the gauging station to estimate QMED and pooling group analysis to estimate higher return period flows. The statistical estimates are therefore considered more reliable than the unscaled ReFH results and the ReFH flow estimates were scaled to fit the FEH statistical peak flow estimates. The high ReFH design flows may indicate that the ReFH estimates of the design event values of the initial soil moisture content are not representative for the Pincey Brook catchment.

A hydrological analysis similar to that described for the existing Pincey Brook catchment was undertaken for the Pincey Brook with the proposed M11 Junction 7A road scheme in place. The impacts of the proposed road scheme on the Pincey Brook catchment hydrology are as follows:

(1) Referring to the with-scheme plan in Annex B, the B183 road alignment will provide a barrier to natural catchment runoff presently draining towards the Pincey Brook reach represented by inflow extent "Lateral 2". The small triangular catchment area represented by the hatched polygon in the plan will be diverted by a cut-off ditch into the catchment area discharging to inflow location PB4 (upstream of Lateral 2). Hence, the catchment area draining to "Lateral 2" is decreased while the catchment area to PB4 is increased as a consequence of the proposed road scheme.

(2) The discharge rates from the proposed attenuation ponds that are to discharge to the Pincey Brook will be restricted based on reduced existing discharge rates and/or greenfield runoff rates, and are insignificantly small compared to the flows in the Pincey Brook from a 52 km^2 catchment. Therefore no specific allowance was made for the proposed road runoff in the with-scheme inflow hydrographs.

The overall impact of the M11 Junction 7A road scheme on the inflows into the Pincey Brook is small. The associated impact on fluvial flood risk due to the changes in flow at inflow locations "PB4" and "Lateral 2" is assessed in the Flood Risk Assessment.

8. References

Centre for Ecology & Hydrology (2007), *Flood Estimation Handbook – Supplementary Report No. 1 (Revitalised FSR/FEH Rainfall-Runoff Method).*

Centre for Ecology & Hydrology (1999), *Flood Estimation Handbook (Volume 1 to 5).*

Environment Agency (2015), *Flood Estimation Guidelines (Technical Guidance 197_08).*

Halcrow (2010), *Stort Modelling and Mapping Flood Risk Study.*

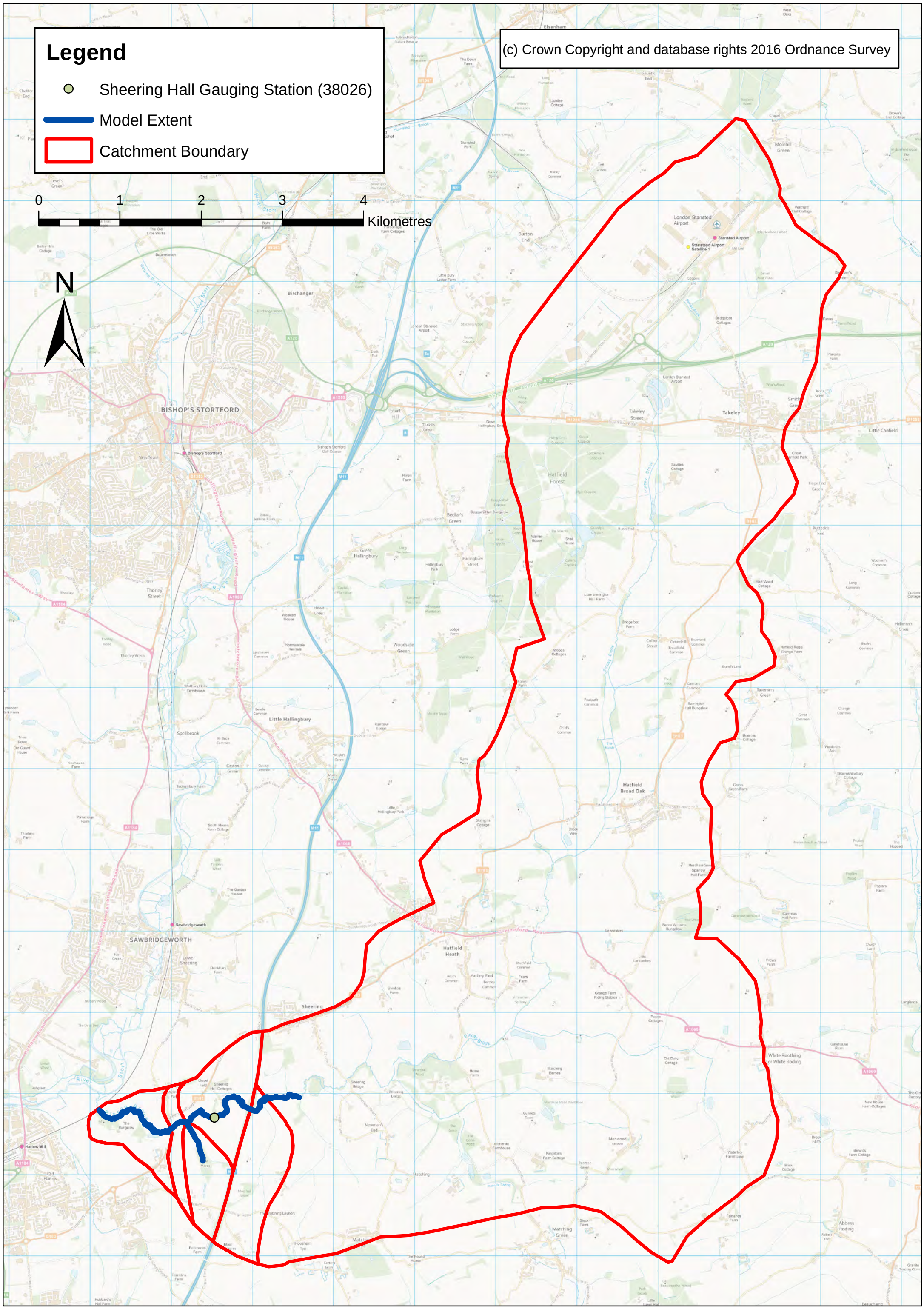
Jacobs (2015), *M11 Junction 7A – Channel Survey Pincey Brook (Drawing No's. JG15-164/XSEC/01 to JG15-164/XSEC/07).*

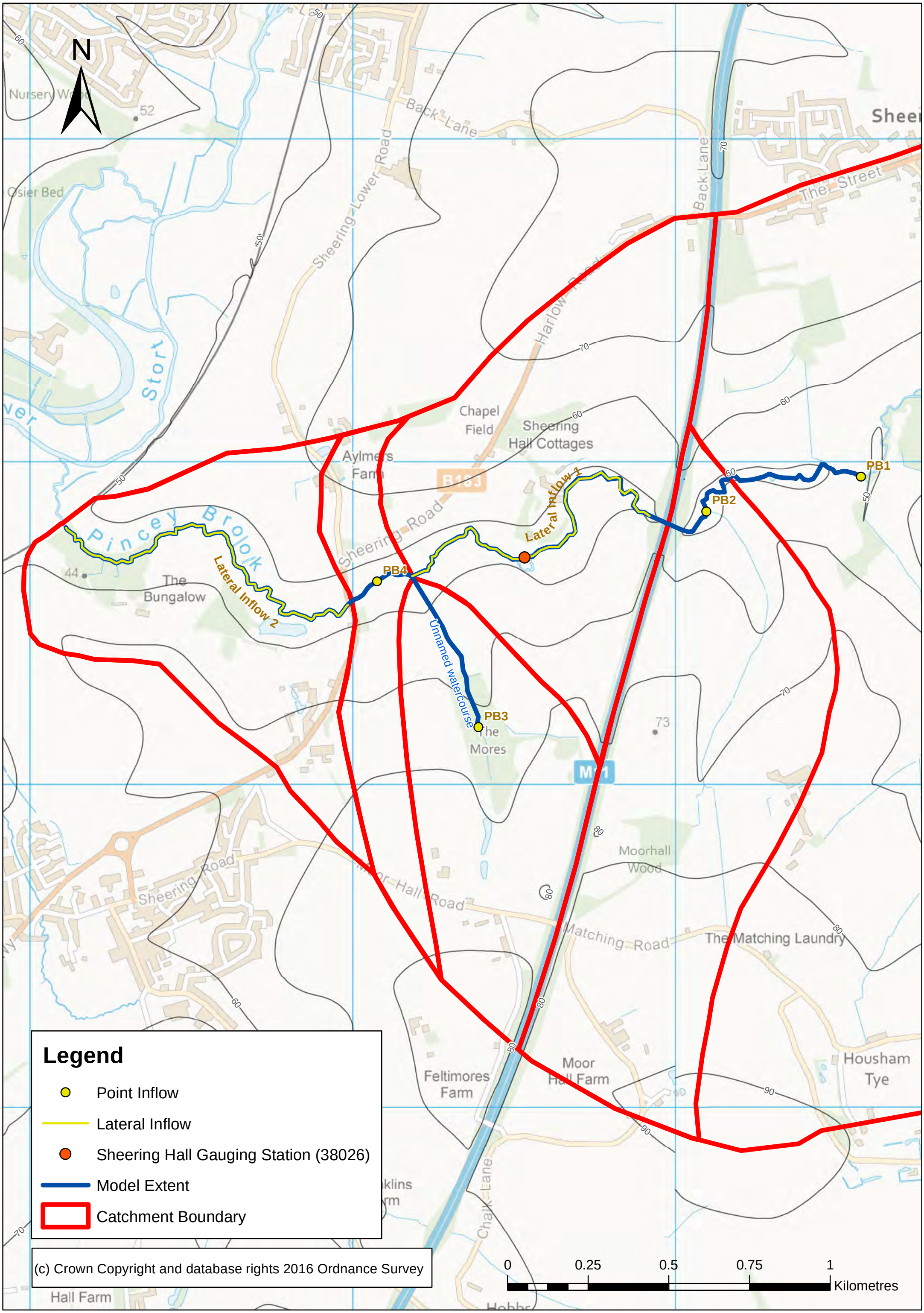
Kjeldsen (2008), *Improving the FEH statistical procedures for flood frequency estimation. Science Report SC050050, Environment Agency*.

Annex A Pincey Brook Existing Condition Catchment Maps

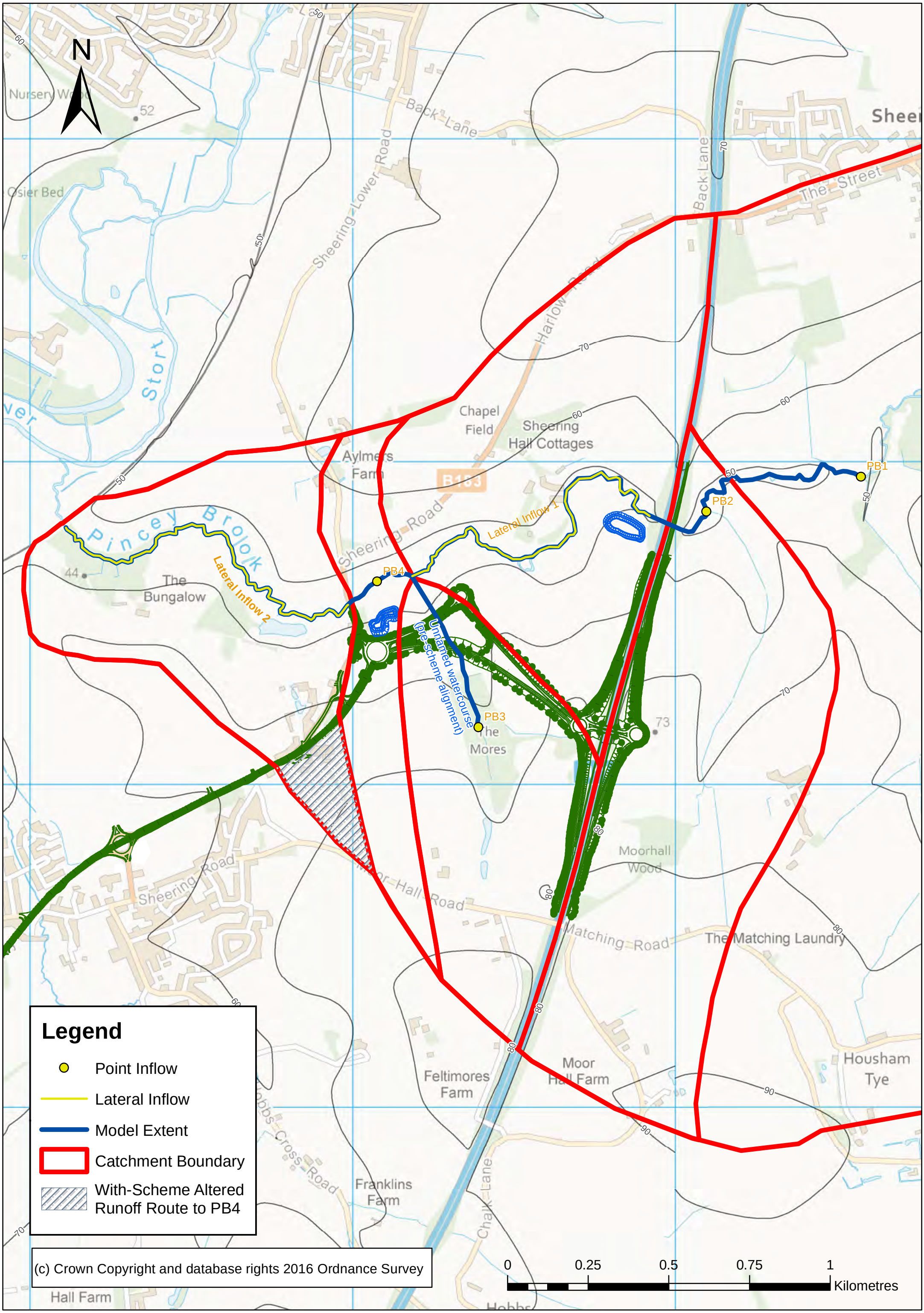
Figure A.1 Pincey Brook Model Extent and Subcatchments

Figure A.2 Pincey Brook Model Inflows

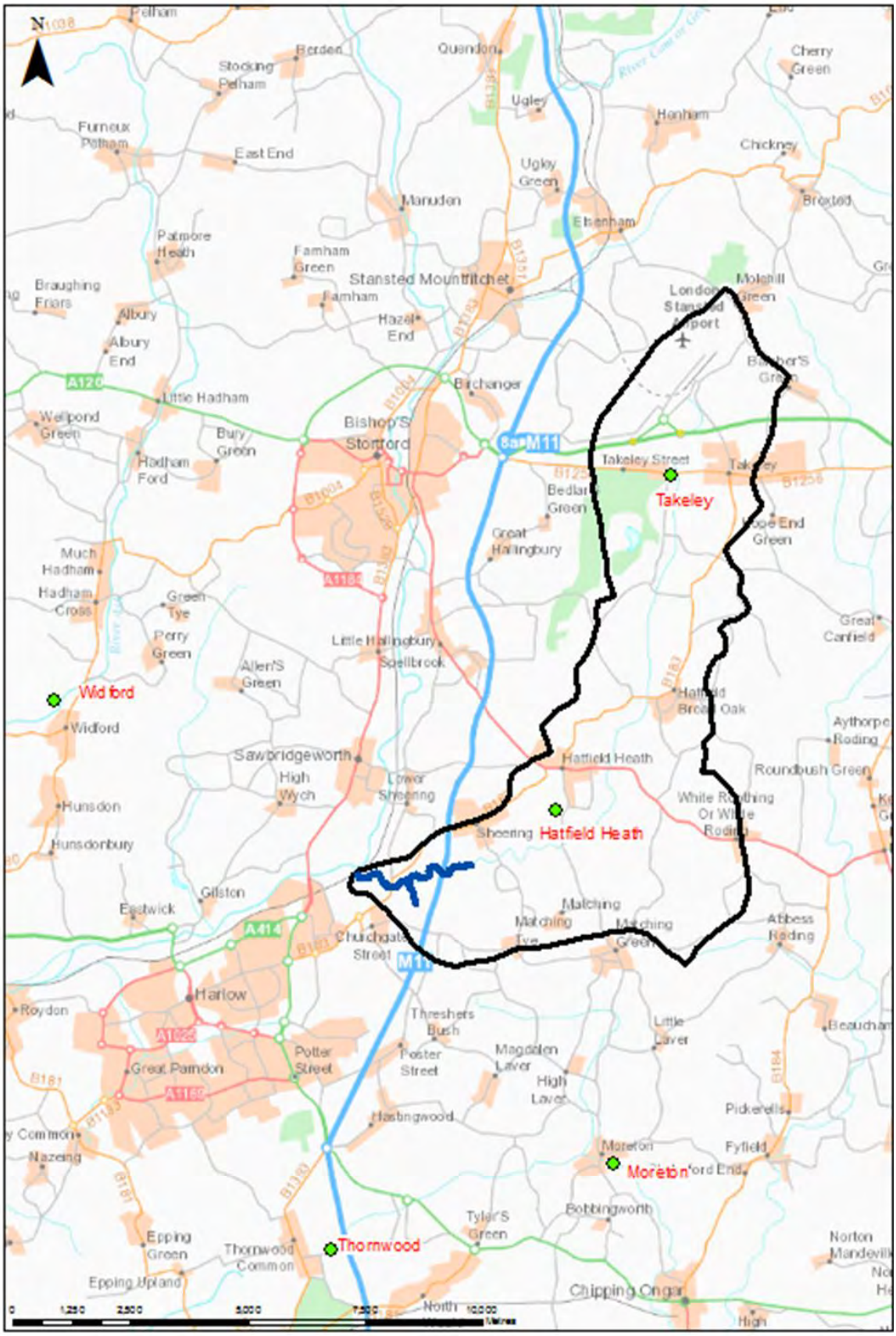

Legend
Sheering Hall Gauging Station (38026)
Model Extent
Catchment Boundary
(c) Crown Copyright and database rights 2016 Ordnance Survey
0
1
2
3
4
Kilometres
N
BISHOP'S STORTFORD
SAWBRIDGEWORTH
Birchanger
Hatfield Forest
Hatfield Broad Oak
Hatfield Heath
Sheering
Little Hallingbury
Great Hallingbury
Takeley
London Stansted Airport
Little Canfield
Molehill Green
Spellbrook
Thorley Street
Harlow Mill
Matching
Matching Green
White Roothing or White Roding


N
Legend
Point Inflow
Lateral Inflow
Sheering Hall Gauging Station (38026)
Model Extent
Catchment Boundary
(c) Crown Copyright and database rights 2016 Ordnance Survey
0
0.25
0.5
0.75
1
Kilometres
PB1
PB2
PB3
PB4
Lateral Inflow 1
Lateral Inflow 2
Unnamed watercourse
Pincey Brook
Back Lane
The Street
Sheering Lower Road
Harlow Road
Sheering Road
Chapel Field
Sheering Hall Cottages
Aylmers Farm
B183
The Bungalow
The Mores
M11
Moorhall Wood
Moor Hall Road
Matching Road
The Matching Laundry
Feltimores Farm
Moor Hall Farm
Housham Tye
Chalk Lane
Nursery Wood
Osier Bed
Hall Farm

Annex B Pincey Brook With-Scheme Catchment Map


N
Legend
Point Inflow
Lateral Inflow
Model Extent
Catchment Boundary
With-Scheme Altered Runoff Route to PB4
(c) Crown Copyright and database rights 2016 Ordnance Survey
0
0.25
0.5
0.75
1
Kilometres
PB1
PB2
PB3
PB4
Lateral Inflow 1
Lateral Inflow 2
Unnamed watercourse (pre-scheme alignment)
Pincey Brook
Sheering Lower Road
Back Lane
The Street
Harlow Road
Chapel Field
Sheering Hall Cottages
Aylmers Farm
B183
Sheering Road
The Bungalow
The Mores
Moorhall Wood
Moor Hall Road
Matching Road
The Matching Laundry
Feltimores Farm
Moor Hall Farm
Housham Tye
Hobbs Cross Road
Franklins Farm
Chalk Lane
Hall Farm
Nursery Wood
Osier Bed
Stort
52
44
73

Annex C Pincey Brook Catchment - Rain Gauge Location Map


Takeley
Widford
Hatfield Heath
Moreton
Thornwood
Stansted Mountfitchet
Bishop's Stortford
Sawbridgeworth
Harlow
Great Dunmow
Takeley Street
Little Hallingbury
Great Hallingbury
Matching
Chipping Ongar
Epping
Hatfield Broad Oak
Roxwell
Fyfield
Ongar
M11
A120
A414
A1184
A1122
A1169
A1060
B1004
B1351
B1383
B1181
B1184
B1256
B1257
B1387
B1393
B1183
B1182
B1351
B1368
B1383
B1393
B1004
B1368
B1383
B1393
B1181
B1183
B1182
B1184
B1256
B1257
B1387
B1368
B1351
B1393
B1383

Annex D Sheering Hall Gauging Station (38026) AMAX Flows

Table D.1 AMAX Flow Series at Sheering Hall Gauging Station (38026)

Rank	Water year	Date	Time	AMAX Flow	Data Source	Comments
	(-)	(-)	(-)	(m^3/s)	(-)	(-)
21	1982-1983	22/10/1982	18:30	6.054	Digital Archive	
33	1983-1984	26/01/1984	23:15	2.433	Digital Archive	
31	1984-1985	24/11/1984	06:30	2.673	Digital Archive	
26	1985-1986	26/12/1985	16:15	5.238	Digital Archive	
34	1986-1987	26/08/1987	03:30	2.376	Digital Archive	
9	1987-1988	10/10/1987	02:00	9.211	Digital Archive	
25	1988-1989	17/03/1989	02:00	5.287	Digital Archive	
11	1989-1990	03/02/1990	19:00	8.881	Digital Archive	
38	1990-1991	17/03/1991	09:00	1.852	Digital Archive	
36	1991-1992	23/09/1992	15:45	2.232	Digital Archive	
19	1992-1993	20/10/1992	19:15	6.386	Digital Archive	
17	1993-1994	13/10/1993	08:45	6.697	Digital Archive	
16	1994-1995	29/01/1995	22:00	6.821	Digital Archive	
37	1995-1996	09/01/1996	16:45	2.019	Digital Archive	
40	1996-1997	25/02/1997	23:45	0.834	Digital Archive	
13	1997-1998	16/04/1998	03:45	7.588	Digital Archive	

Rank	Water year	Date	Time	AMAX Flow	Data Source	Comments
32	1998-1999	28/01/1999	18:15	2.572	Digital Archive	
28	1999-2000	28/05/2000	23:00	3.998	Digital Archive	
3	2000-2001	30/10/2000	12:15	11.09	Digital Archive	Non-independent peak removed B
8	2001-2002	21/10/2001	18:15	9.227	Digital Archive	
20	2002-2003	01/01/2003	23:15	6.339	Digital Archive	
30	2003-2004	31/01/2004	20:30	2.955	Digital Archive	Series used : 5169FQ,5169HU,
6	2004-2005	19/11/2004	08:00	10.89	Digital Archive	Series used : 5169FQ,5169HU,
39	2005-2006	14/06/2006	06:15	1.484	Digital Archive	Series used : 5169FQ,5169HU,
27	2006-2007	18/01/2007	21:45	4.953	Digital Archive	
24	2007-2008	20/01/2008	03:15	5.327	Digital Archive	
12	2008-2009	10/02/2009	05:15	8.501	Digital Archive	
23	2009-2010	28/02/2010	22:00	5.601	Digital Archive	
15	2010-2011	18/01/2011	11:45	6.921	Digital Archive	
18	2011-2012	03/05/2012	12:30	6.594	Digital Archive	
14	2012-2013	20/12/2012	20:45	7.014	Digital Archive	
22	2013-2014	07/02/2014	12:00	5.876	Digital Archive	
-	2014-2015	24/11/2014	13:45	5.45	EA	

Annex E Pooling Group Analysis Audit Trail

Pooling Group Analysis Pincey Brook

Pooling group construction (Using WINFAP database Version 3.3.4 of August 2014)

Site of interest

(a) Station Number	GS 38026	(b) Name	Sheering Hall Gauging Station

Name of saved **.feh** group file	Pincey_Brook_Pooling_Rev 1.feh
Target return period (years) for 5T rule	100

Initial Pooling group details

Total number of sites	15	Total number of years	704

Total number of initial high discordancy sites	0
List them: GS Number	
Total number of short records (< 7 years) removed	0
List them: GS Number	
Number of pooled years after sites removed	

Subject Site Details

Is subject site included as Rank 1 in pooled group: ~~yes~~ no

If no state reason why: Site only rated up to QMED on NRFA. Not suitable for pooling.

Test statistics on validity of pooling group for flood frequency analysis

Heterogeneity test H2 value = 3.30

Status			
	Review not necessary		H2 < 1
	Review optional		1 < H2 < 2
	Review desirable	✓	2 < H2 < 4
	Review essential		H2 > 4

					Value
Goodness-of-fit test	Z values	GL	~~acceptable~~	/ not acceptable	2.331
		GEV	acceptable	/ ~~not acceptable~~	-1.442
		PT3	acceptable	/ ~~not acceptable~~	-1.025
	other				

(Note: in the FEH the GL is the generally favoured distribution for use)

ACTION is construction of flood frequency curve valid?

No ~~Yes~~ Check suitability of sites in the pooling group

Revision of Pooling Group

Revision No. 1

Station Number	Reason for changes in pooling group
26003, 33032, 34012,	Removed, BFIHOST of 0.880, 0.968 and 0.965
33054, 39033, 39042	Removed, BFIHOST of 0.906, 0.766 and 0.865
37014, 34005, 42011, 43014, 53023, 54036, , 34005, 20007	Added to increase to 700 station years

Number of sites 9 Years 439

Heterogeneity test H2 value = 1.49

Status			
	Review not necessary		H2 < 1
	Review optional	✓	1 < H2 < 2
	Review desirable		2 < H2 < 4
	Review essential		H2 > 4

Note: FEH Vol.3, chapter 16.3.2: "The ideal pooling-group is homogeneous. However, a representative but heterogeneous pooling-group gives better flood frequency estimates than either single-site data or a pooling-group that has been made homogeneous by inappropriately removing sites. In general, it is anticipated that a significant proportion of pooling-groups will remain heterogeneous, even after review."

Revision of Pooling Group

Revision No. 2

Station Number	Reason for changes in pooling group
34005	Removed, unacceptable FPEXT
20007	Removed, unacceptable PROPWET

Number of sites	11	Years	524

Heterogeneity test H2 value = 2.502

Status			
	Review not necessary		H2 < 1
	Review optional		1 < H2 < 2
	Review desirable	✓	2 < H2 < 4
	Review essential		H2 > 4

Goodness-of-fit test	Z values				Value
		GL	acceptable	/ ~~not acceptable~~	1.515
		GEV	acceptable	/ ~~not acceptable~~	-1.619
		PT3	acceptable	/ ~~not acceptable~~	-1.223
	other				

ACTION is construction of flood frequency curve valid?

~~No~~ Yes

Comment? Review carried out as suggested from heterogeneity test, and group found to be appropriate

Flood frequency analysis of pooling group

Distributions selected	GL	✓	PT3	✓
	GEV	✓	other	

Standardisation method selected Median (this acts as a check as median is the only method allowed within the pooling group method)

~~Mean~~

Construct flood frequency curve

				If yes		
URBEXT updated	~~yes~~	no	from		to	
Urban adjustment*	yes	~~no~~				

Value of QMED = 5.60 m^3/s

GL		
Return period (yrs)	**Growth factors**	**Flow (m^3/s) (to subcatchment only)**
2	1.000	5.60
5	1.41	7.91
10	1.68	9.41
20	1.94	10.88
25	2.03	11.36
50	2.30	12.90
100	2.59	14.52
1000	3.68	20.61

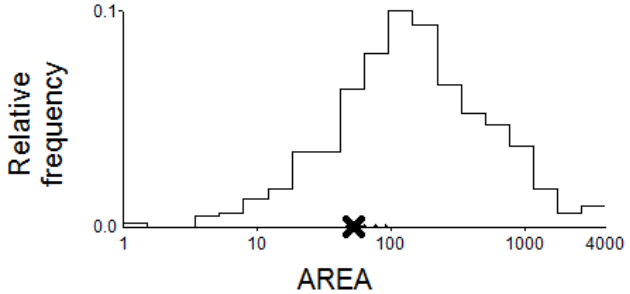
GEV		
Return period	**Growth factors**	**Flow (m^3/s) (to subcatchment**

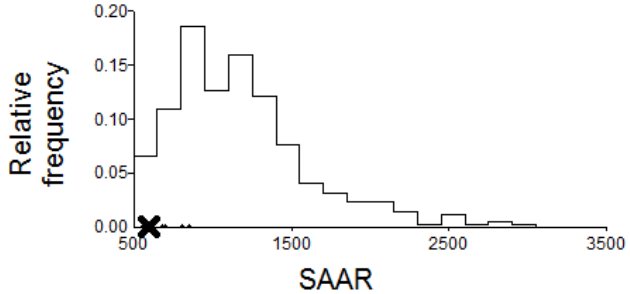
(yrs)		only)
2	1.000	5.60
5	1.46	8.18
10	1.73	9.69
20	1.97	11.03
25	2.04	11.37
50	2.24	12.54
100	2.43	13.55
1000	2.93	16.41

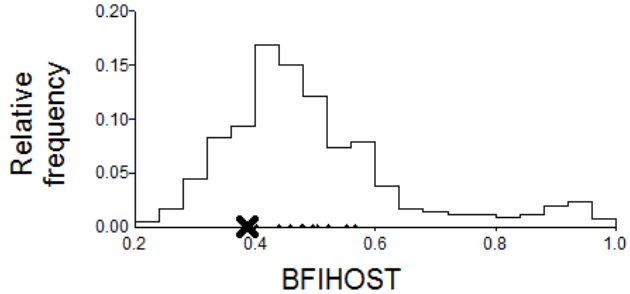
PT3		
Return period (yrs)	**Growth factors**	**Flow (m^3/s) (to subcatchment only)**
2	1.00	5.60
5	1.46	8.15
10	1.72	9.64
20	1.96	10.96
25	2.03	11.35
50	2.24	12.54
100	2.43	13.61
1000	3.03	16.97

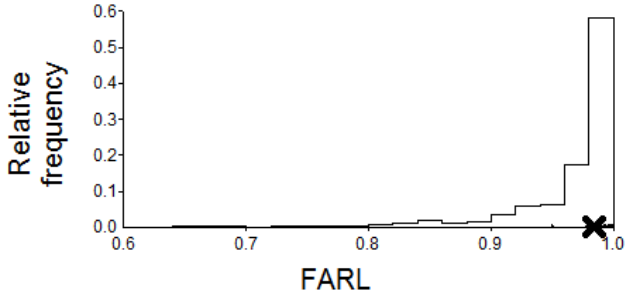
The GL (Generalised Logistic) distribution was selected as it has an acceptable goodness-of-fit and is described in FEH and is the preferred distribution in the UK.

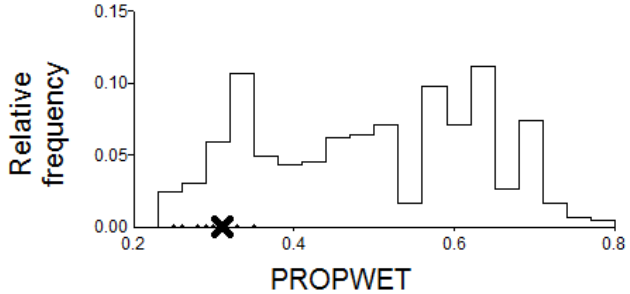
Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
36003 (Box @ Polstead)	0.163	49	3.841	0.31	0.109	0.144
36007 (Belchamp Brook @ Bardfield Bridge)	0.235	48	4.628	0.384	0.129	2.701
36004 (Chad Brook @ Long Melford)	0.3	45	4.938	0.306	0.199	0.293
37016 (Pant @ Copford Hall)	0.362	47	8.502	0.285	0.049	0.111
30004 (Lymn @ Partney Mill)	0.455	50	6.778	0.236	0.059	0.81
37003 (Ter @ Crabbs Bridge)	0.627	48	4.991	0.248	-0.037	0.447
38002 (Ash @ Mardock)	0.721	71	6.76	0.288	0.075	0.336
53017 (Boyd @ Bitton)	0.735	39	13.073	0.243	0.112	0.723
41022 (Lod @ Halfway Bridge)	0.782	39	16.044	0.287	0.214	1.292
37014 (Roding @ High Ongar)	0.815	49	10.756	0.246	-0.152	1.757
54036 (Isbourne @ Hinton on the Green)	0.876	39	13.924	0.329	0.368	2.386
Total		524				
Weighted means				0.291	0.102	

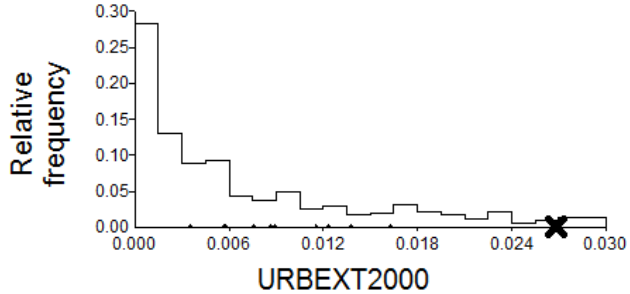

Relative frequency
AREA

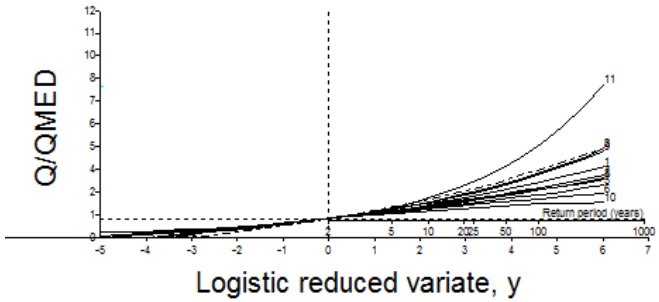

Relative frequency
SAAR

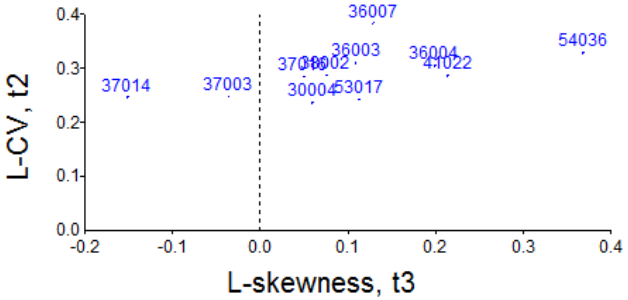

Relative frequency
BFIHOST


Relative frequency
FARL


Relative frequency
PROPWET


Relative frequency
URBEXT2000


Q/QMED
Return period (years)
Logistic reduced variate, y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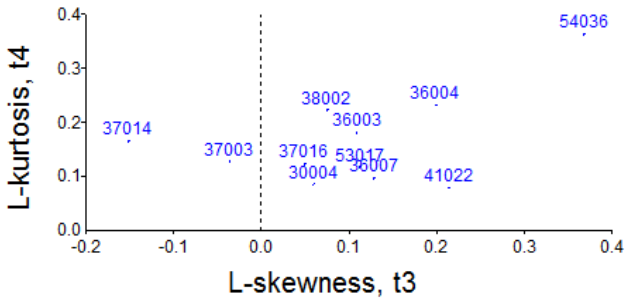
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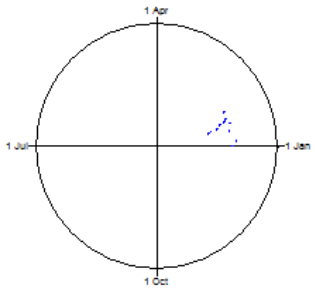
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Appendix E. M11 Junction 7A Hydraulic Modelling Report

M11 Junction 7A

Ringway Jacobs / Essex County Council

Hydraulic Modelling Report

Document history and status

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Jacobs U.K. Limited

1180 Eskdale Road
Winnersh, Wokingham
Reading RG41 5TU
United Kingdom
T +44 (0)118 946 7000
F +44 (0)118 946 7001
www.jacobs.com

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1. Introduction

1.1 Background

Essex County Council is developing a proposal for improving access to and from the M11 in the Harlow area. The project is for the provision of a new motorway junction (Junction 7A) on the M11 between existing Junctions 7 and 8, a proposed link road to Sheering Road (B183) linking the M11 to Harlow, and proposed widening and improvement works to Sheering Road/Gilden Way (B183).The Scheme is located in the County of Essex and its location is shown on Figure 1. A Flood Risk Assessment (FRA) is required to meet relevant local and national planning legislation and inform the design and planning processes. This report summarises the hydraulic modelling work undertaken for the Pincey Brook to assist the assessment of both the flood risk to the development site from fluvial flooding in the pre-scheme conditions and the potential effect of the Scheme on the flooding regime in order to support the FRA for the proposed development.

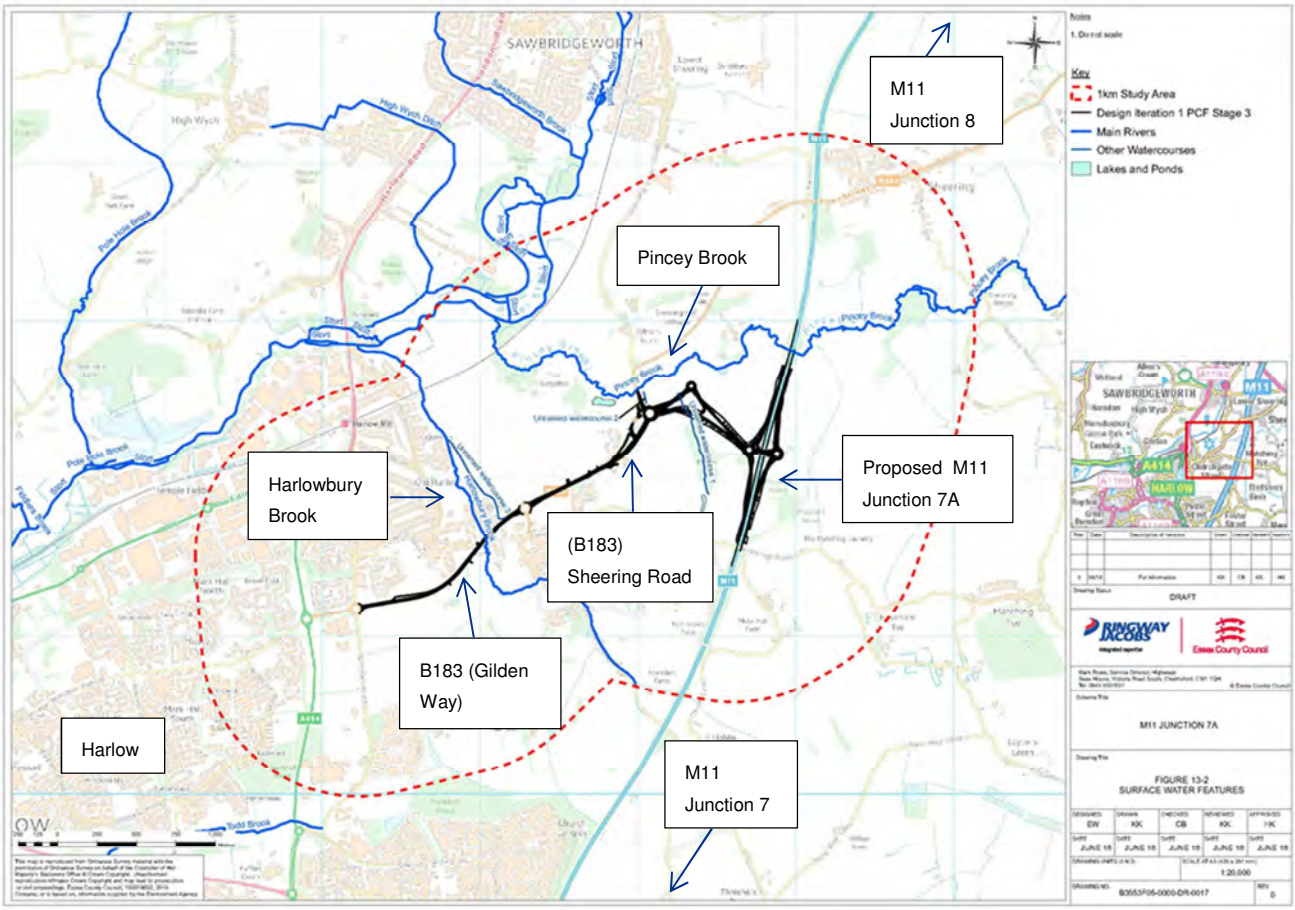


Figure 1 - M11 Junction 7A scheme Location Plan

1.2 Scope of Works

The hydraulic modelling only covers the fluvial nature of the flood risk and design aspects for areas of the scheme.

The modelling work consisted of the following:

- Baseline (existing situation) model development;
- Baseline Model calibration/verification;

- Baseline runs for a range of flood events with a 50%, 20%, 5%, 1% and 0.1% Annual Exceedance Probability (AEP). Impact of Climate Change on the 1% AEP event was also simulated;

- Sensitivity tests;

- With-scheme model development and simulation of the same series of flood events mentioned above;

- Flood mapping.

1.3 Site description

Parts of the proposed scheme lie within the Pincey Brook River Catchment. The Pincey Brook is a tributary of the River Stort and is classified as "Main River" on the Environment Agency consultation maps. At the M11 crossing the Pincey Brook serves a catchment area of approximately 52 km^2 and flows for further 2880m in the eastern-western direction before discharging into the River Stort. The watercourse is situated immediately to the north of the proposed development.

Within the proposed study area there is also an unnamed tributary originating from a wooded area called the Mores, serving a catchment area of approximately 0.7 km^2 and discharging into the Pincey Brook.

The main land use at the development site is predominantly rural. However, there are residential properties on both sides of the B183, and Mayfield Farm to the south east of the B183, which are adjacent to the proposed development area. The residential town of Harlow is the largest urban area and is located to the south-west of the scheme.

1.4 Proposed development

The proposed development includes a link road between the M11 and the B183 and will involve the construction of slip roads and roundabouts which will allow access and egress to and from the motorway in both directions. The development also involves a series of improvement works to the B183 (called Sheering Road at the Northern end of the scheme and Gilden Way at the southern end). The improvement works to the B183 also involves the re-route of the road as it approaches the link road element of the scheme.

The proposed link road crosses the small unnamed watercourse that drains into the Pincey Brook. In the present condition the downstream end of the unnamed watercourse appears to be culverted along a length of approximately 125m. The survey undertaken by Jacobs in 2015 showed two 300mm outfalls into Pincey Brook. Both outfalls appear to be in poor condition and it is believed that only one was working at the time of the survey.

In the proposed scenario the open section of the unnamed watercourse will be re-routed to the east of the existing route and will have two culverted sections under the proposed road embankments. The current culverted section of the watercourse will be abandoned and replaced by an open channel to the west of the existing route joining Pincey Brook approximately 190m downstream of the current point of discharge.

1.5 Previous studies

The following existing hydraulic models provided by the Environment Agency were available for the present study:

- An Infoworks RS model of the Middle Stort built by Faber Maunsell[1];
- An ISIS/Tuflow model of the Upper and Middle Stort built by Halcrow[2].

[1] Middle Stort Flood Mapping Study, Faber Maunsell, 2007

In the 2010 ISIS/Tuflow model the Pincey Brook was represented only as a ReFH inflow into the River Stort. The existing Infoworks RS model targeted the River Stort, and included the downstream section of the Pincey Brook, from approximately 250m upstream of the Sheering Road crossing to the junction with the Stort. However, the included section did not extend far enough upstream to cover the development area, and the Pincey Brook section of the model was not detailed enough for the FRA requirements. Therefore Jacobs deemed it necessary to build a new hydraulic model for the Pincey Brook. The upstream model boundary has been located upstream of the M11 crossing, and the downstream boundary is at the junction with the River Stort. The unnamed tributary encroached by the proposed development is also represented in the new model (see Section 2.3).

1.6 Fluvial Flood Risk

The Environment Agency flood zone maps covering the M11 J7A development area are shown in Figure 2.

Figure 2 shows that most of the development area is situated within Flood Zone 1, i.e. the zone with an annual probability of fluvial flooding of less than 0.1% (1 in 1000) annual probability. Between the M11 and B183 the Pincey Brook flows through rural land and therefore there are few flood receptors.

The only flood receptors identified in Flood Zones 2 and 3 of Pincey Brook are:

- The M11 culvert crossing of the Pincey Brook;
- The B183 crossing of the Pincey Brook;
- The railway crossing of the Pincey Brook;
- Localised sparse housing/sheds at Sheering Hall, immediately west of the M11;
- Localised sparse housing/sheds at Gibberd Gardens, immediately east of the railway line.

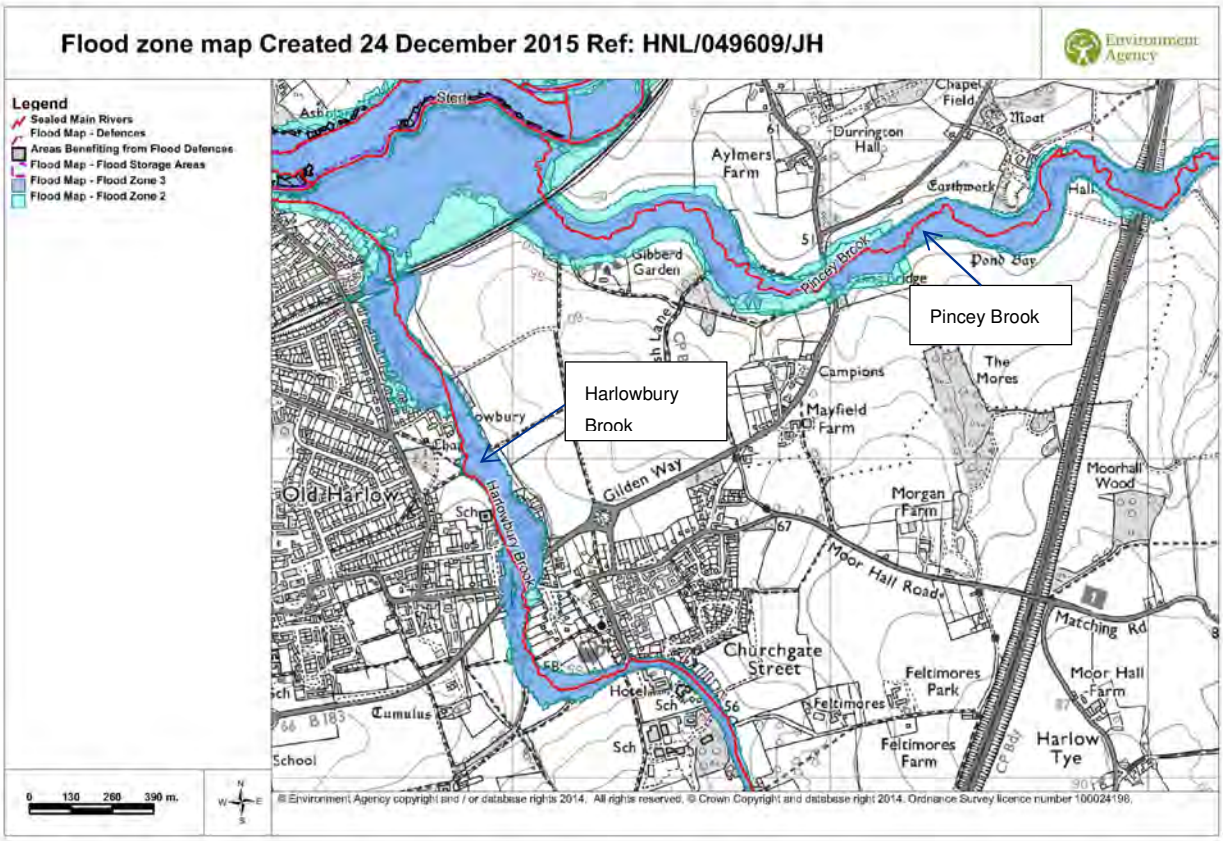


Figure 2 - Environment Agency flood zone maps within the study area

[2] Stort Modelling and Mapping Flood Risk Study, Halcrow, 2010

2. Baseline Hydraulic modelling

2.1 Introduction

A hydraulic model of the River Pincey Brook and its unnamed tributary was developed to assess the baseline flood levels and extents in the vicinity of the proposed scheme. The hydraulic model was built using a linked One dimensional (1D) / Two dimensional (2D) technique, where the river channel is represented as a 1D component using Flood Modeller software and it is linked to the floodplain, which is represented in 2D, using TUFLOW software. The linked 1D/2D modelling approach meant that the model dynamically transferred the water between the watercourses and the floodplain.

2.2 Available data

The following key sources of information have been used in this study:

- Ordnance Survey 1:10,000 mapping;
- Environment Agency flood mapping of Flood Zone 2 and Flood Zone 3;
- Detailed topographic survey of the watercourses undertaken by Jacobs in 2015/2016;
- 1m resolution Digital Terrain Model (DTM) data of the area of interest, downloaded from the LiDAR open source website[3];
- Infoworks RS model of the Middle Stort;
- ISIS/Tuflow model of the Upper and Middle Stort.

2.3 Baseline Model Development

2.3.1 Software used

The hydraulic model was constructed using the following hydraulic modelling software packages:

- 1D component: Flood Modeller v. 4.1.1.160 (64bit double precision)

- 2D component: Tuflow 2016-03-AA-iDP-w64

A model schematisation plan is shown in Figure 4. Model reference files are provided in Appendix A of this report.

2.3.2 Model boundaries

The modelled reach of Pincey Brook extends from approximately 750m upstream of the M11 crossing (cross section PIN01_3535) to the junction with the River Stort (cross section PIN00_0000), over a distance of approximately 3,780m. The Tributary extends from approximately 90m into the wooded area at The Mores (cross section MOR01_0427) to its outfall into the Pincey Brook (unit MOR01_0000c), over a distance of approximately 427m. These reaches are considered appropriate for this assessment as these extents provide a representation of conditions upstream and downstream of the proposed scheme.

A hydrological analysis of the Pincey Brook catchment has been carried out and is reported separately to this report[4]. Design Flood flow hydrographs were used as upstream boundaries within the Flood Modeller model. The locations of these inflows are shown in Figure 3 and peak values are provided in Table 1.

To improve stability it was necessary to set a minimum flow of 0.1m^3/s on the unnamed tributary due to its steepness.

[3] http://environment.data.gov.uk/ds/survey/
[4] M11 Junction 7A, Pincey Brook Design Flood Hydrology, Jacobs, 2016

An analysis has been undertaken to establish the critical storm duration for each reach at the location of the proposed M11 scheme. This analysis established that a storm duration of 24 hours was critical for the scheme location. The table below shows peak inflows for each event for the 24 hour storm duration.

An allowance for climate change has been included in the modelling by increasing the fluvial inflows for the 1% AEP event by 35% and 70%, in accordance with climate change guidance from the Environment Agency[5].

Table 1 - Flood Hydrograph Peak inflows input to the baseline model

Inflow	Easting (m)	Northing (m)	Annual Exceedance Probability (AEP)						
			50%	20%	5%	1%	1% (+35% CC)	1% (+70% CC)	0.1%
			Peak Inflows (m^3/s)						
PB1	550577	212953	5.56	7.84	10.79	14.41	19.45	24.49	33.12
PB2	550098	212846	0.24	0.34	0.47	0.63	0.84	1.06	1.45
PB3	549392	212177	0.10	0.14	0.19	0.25	0.34	0.43	0.58
Lateral 1	s. 549922 e. 549186	s. 212832 e. 212645	0.15	0.21	0.29	0.39	0.53	0.67	0.91
PB4	549078	212629	0.05	0.07	0.10	0.13	0.18	0.23	0.31
Lateral 2	s. 548988 e. 548112	s. 212557 e. 212796	0.13	0.18	0.25	0.33	0.45	0.56	0.77
s. = Start , e. = End, CC = Climate Change									

The downstream boundary was set as Normal Depth boundary with a 1: 1667 slope based on the local gradient of the River Pincey Brook at its downstream modelled extent.

Sensitivity analysis (See Section 5.1.3) shows that in the vicinity of the scheme, the model is not sensitive to adjustment of the downstream boundary.

[5] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

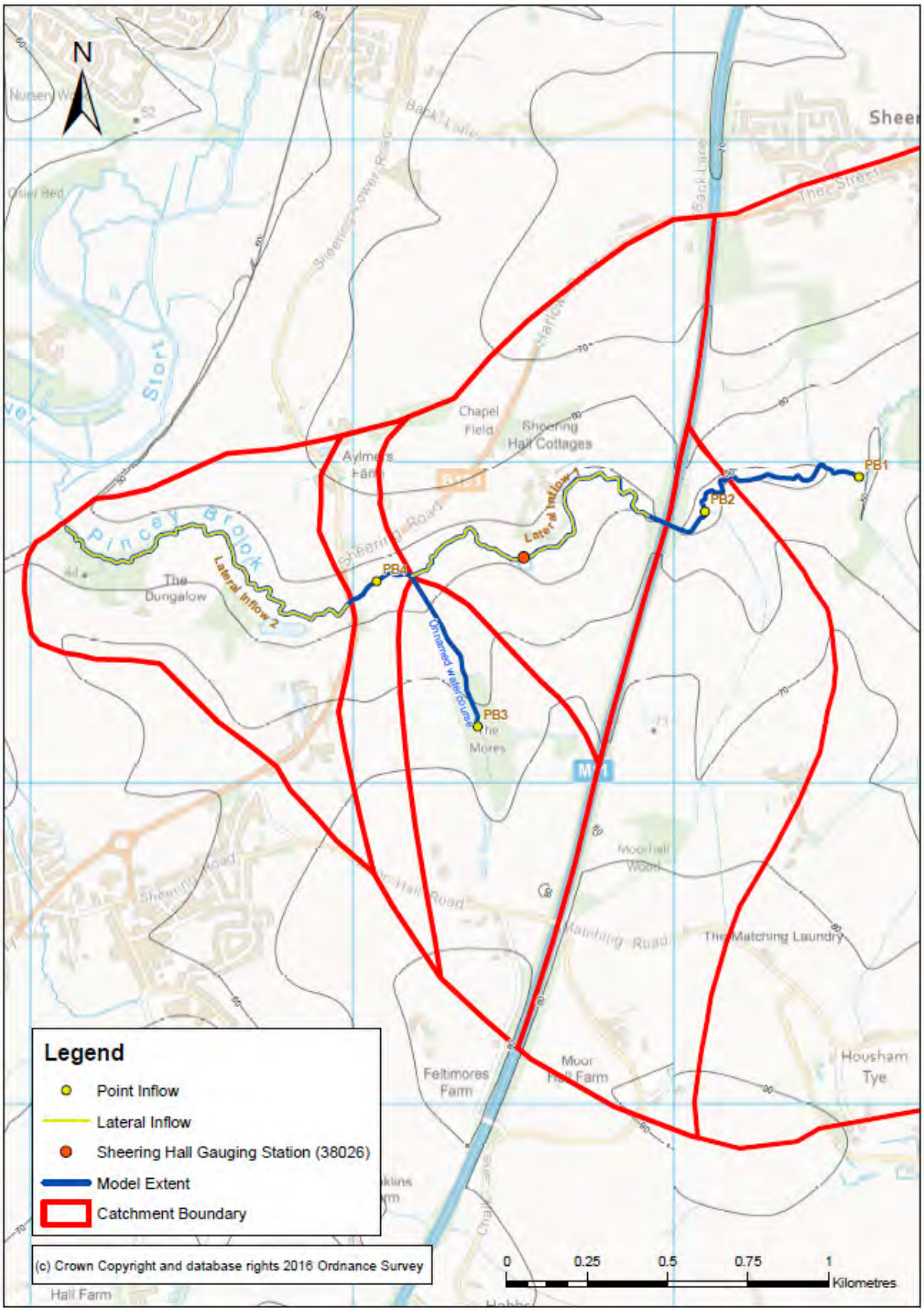


Figure 3 - Hydraulic Model Boundaries

2.3.3 River Channel representation

Open channel cross sections of Pincey Brook and the unnamed tributary were included in the 1D component of the model using the channel cross-sectional survey carried out by Jacobs in 2015/2016.

Cross sections for Pincey Brook downstream of the railway culvert were taken from the 2007 Faber Maunsell Infoworks RS model.

Manning's "n" values to account for the hydraulic friction of the river channel bed were initially assigned based on survey photographs of the bed material in the watercourse and available guidance in literature (e.g. Open Channel Hydraulics, Ven Te Chow, 1959). Some of them (PIN01_1925-PIN01_1872) were subsequently modified following the calibration of the model (see Section 2.5). The adopted values for Manning's "n" roughness coefficients used in the baseline model are given in Table 2.

Table 2 - River channel Manning's "n" values used in the hydraulic model

Watercourse	Reach	Manning's "n"
Pincey Brook (Upstream of railway culvert)	PIN01_3535-PIN01_3473	0.045
	PIN01_3473- PIN01_2784	0.045
	PIN01_2681- PIN01_2272	0.035
	PIN01_2266- PIN01_2192	0.045
	PIN01_2164-PIN01_1952	0.045
	PIN01_1925- PIN01_1872	0.200
	PIN01_1745- PIN01_1627	0.045
	PIN01_1533- PIN01_1404d	0.060
	PIN01_1330u- PIN01_1270	0.045
	PIN01_1199- PIN01_1048	0.050
	PIN01_0578- PIN01_0000	0.060
Pincey Brook (Downstream of railway culvert)	PIN00_0200- PIN00_0000	0.070
Unnamed Tributary	MOR01_0427	0.060
	MOR01_0277-MOR01_0126	0.060

2.3.4 Hydraulic Structure Representation

A total of eight structures along the watercourses were included in the 1D model and their modelling schematisation is detailed in Table 3.

Table 3 : Hydraulic structures represented in the baseline model

Watercourse	Location	Type of structure	Cross section	Schematisation
Pincey Brook	83m upstream of M11	Concrete slab over watercourse	PIN01_2868	Arch bridge unit + spill unit to represent bridge deck.
	M11 crossing	Double rectangular conduit under the M11	PIN01_2784 - PIN01_2681	Double rectangular conduit + inlets and outlets. Deck represented in 2D domain
	211m downstream of M11	Concrete arch footbridge	PIN01_2470	Arch bridge unit + spill unit to represent bridge deck.
	Sheering Hall	Concrete flat bridge with sloping deck over double weir structure	PIN01_2272	Orifice unit + spill unit to represent bridge deck.
	Gauging Station 38026 at Sheering Hall	Flat-V weir	PIN01_1967u	Flat-V weir unit
	Ealing Bridge (B186 crossing)	Brick arch bridge	PIN01_1278	Arch bridge unit + spill unit to represent bridge deck.
	Railway crossing	Brick arch bridge + 2 parallel circular relief pipes	PIN01_0000 - PIN00_0200	Sprung arch conduit + 2 parallel circular pipes
Unnamed Tributary	Approx. 125m upstream of junction with Pincey Brook	2 no. 300mm dia. pipes (with one not functioning)	MOR01_0126 - MOR01_0000c	Circular conduit

It should be noted that the structure under the Railway line has not been surveyed due to safety and access issues. Structure dimensions were therefore estimated from site visit photos. Sensitivity tests carried out on these dimensions (See Section 5.1.3) demonstrate that the model results at the location of the scheme are not sensitive to assumptions made for this structure.

2.3.5 Floodplain representation

The floodplain topography was represented in the 2D component of the hydraulic model using 1m horizontal resolution LiDAR data. The 2D model was based on fixed grid of square cells of 4m side informed with the LiDAR data and hydraulic friction information.

Hydraulic friction across the floodplain was represented using landuse types identified in the OS MasterMap data (using the "Feature Code" attribute). The Manning's "n" roughness coefficient associated with each Feature Code is provided in Table 4.

Table 4 - Floodplain hydraulic roughness values used in the 2D model

OS Master Map Feature Code	Manning's "n"	Land cover Group
10056	0.055 (set as default)	General green areas
10021	1.0	Buildings
10089, 10210	0.02	Water
10062	0.30	Glasshouse
10089	0.035	Inland water
10111	0.10	Natural Environment / landform
10119/10123	0.02	Path
10167	0.04	Rail
10172	0.02	Road or track
10185	0.03	Structure
10217	0.04	Unclassified

No floodplain features such as culverts, embankments and drains important for flow connectivity and flood risk were identified in the area of study.

2.3.6 Linking of watercourse and floodplain

The linked 1D/2D modelling approach meant that the model dynamically transferred the water between the watercourses (1D) and the floodplain (2D). The flow exchange at the link in this approach is controlled by the bank crest levels (see Figure 4).

In general it was found a good correspondence between DTM and top of bank elevations from the cross sectional survey undertaken by Jacobs in 2015. When it was not possible to establish such a correspondence, the top of bank elevations in the 2D domain were reinforced with zlines informed by the elevations from the cross sectional survey.

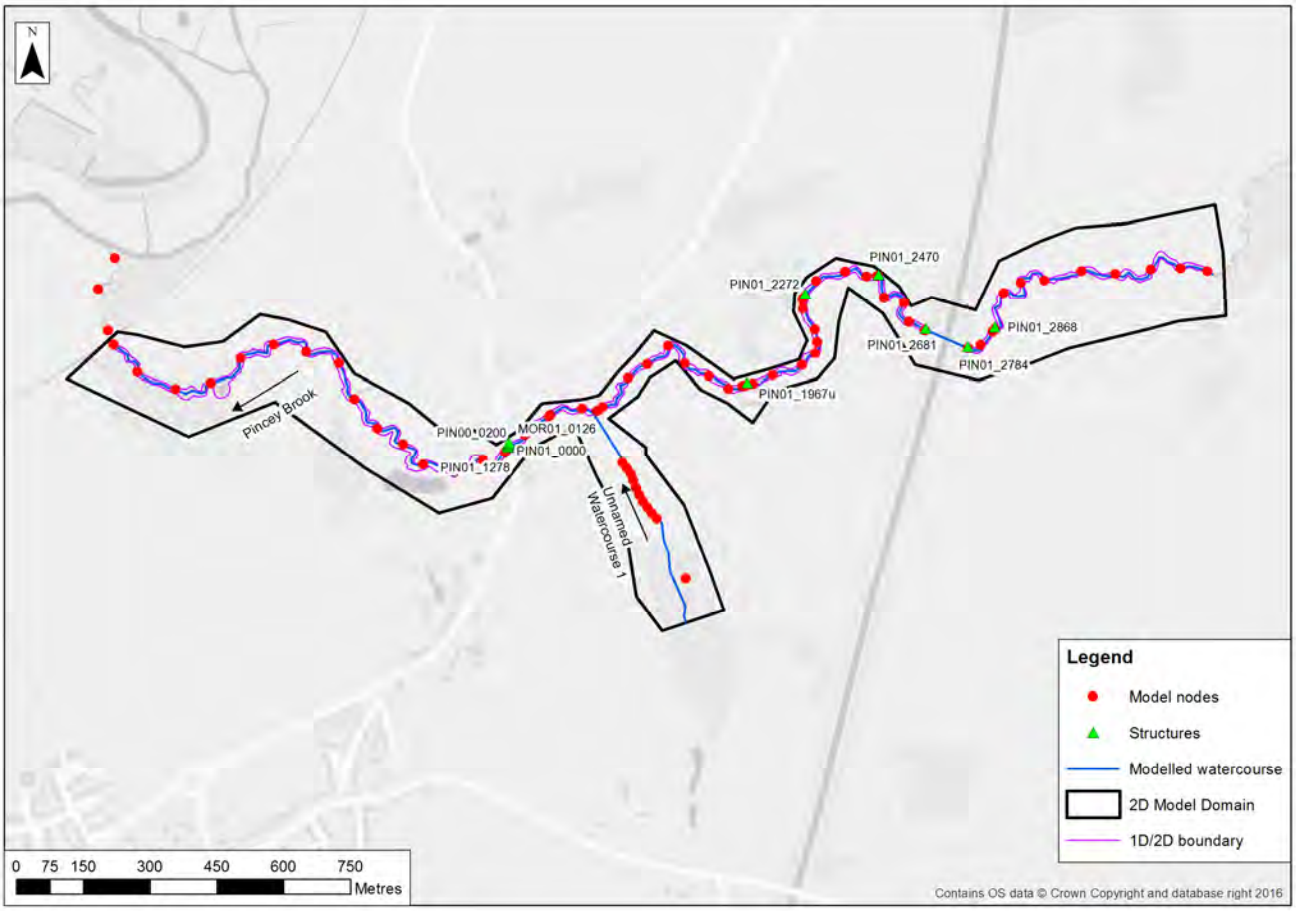


Figure 4 - Baseline hydraulic model schematisation

2.4 Model performance

Run performance has been monitored throughout the model build process and then during each simulation carried out, to ensure the optimum model convergence was achieved.

In the 1D model the convergence plots produced as .bmp files were checked. As shown on the example in Figure 5, convergence is generally within tolerance for all the duration of the simulation. Some isolated spikes are present, but these are far from the inflow and outflow peak so this is deemed acceptable.

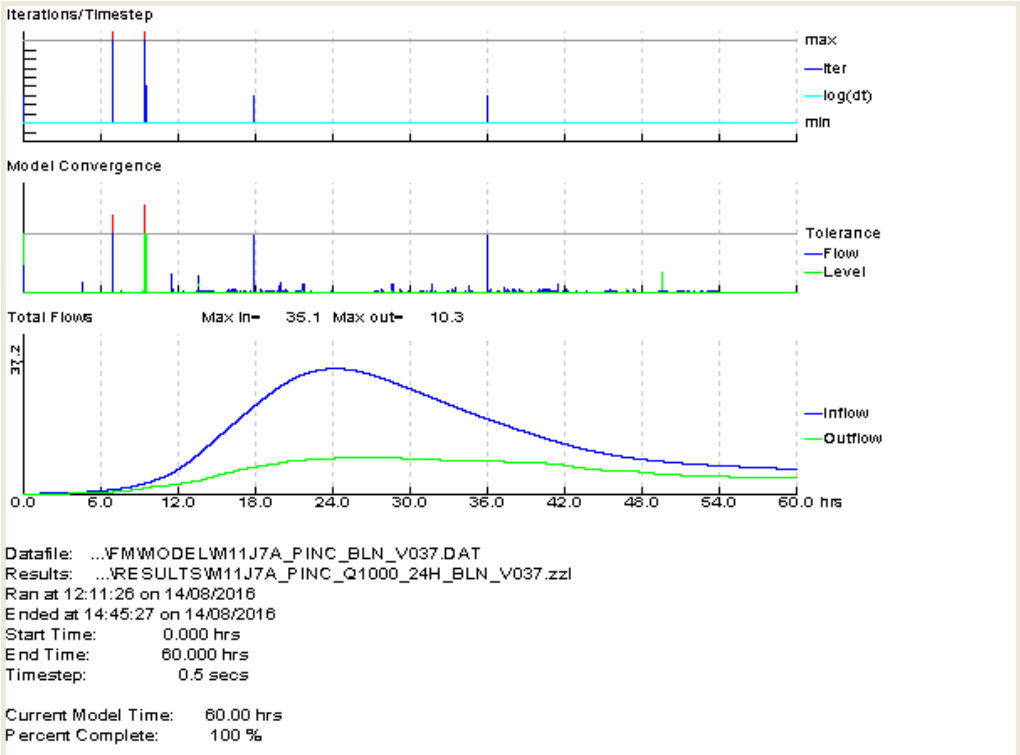


Figure 5 - 1D model convergence plot for the simulation of the 0.1% AEP flood event

The cumulative mass error reports output from the TUFLOW 2D model have been checked. The recommended tolerance range is +/- 1% Mass Balance error. The change in volume through the model simulation has also been checked.

As shown in Figure 6, high Mass Balance error (up to +3.6%) occurs at the onset of flooding (wetting of the 2D model) but rapidly drop within the recommended tolerance as flood wave reaches its peak. This is deemed acceptable. The change in volume dV shows some spikes at some time, but these occur far from the peak so it is also deemed acceptable.

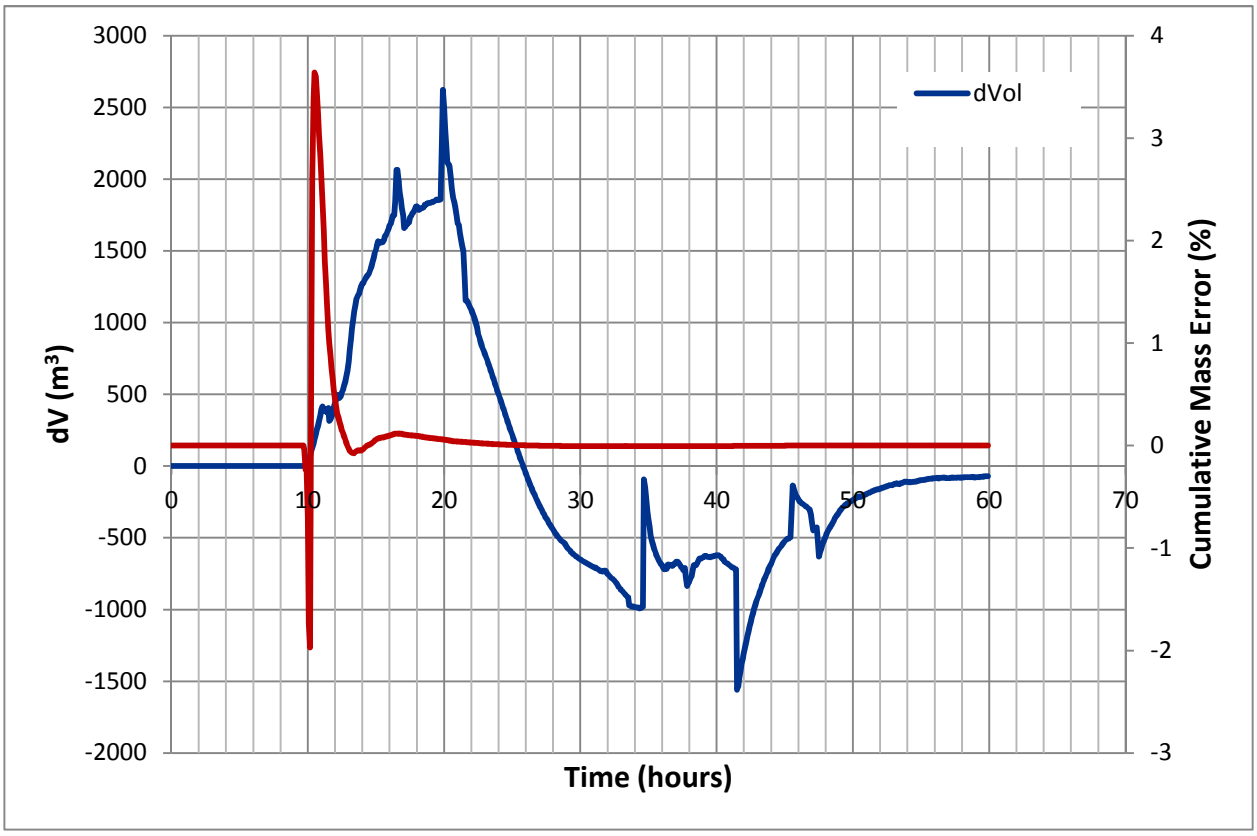


Figure 6 - 2D Cumulative Mass Error and Change in volume for the simulation of the 0.1% AEP event

2.5 Hydraulic model calibration

To improve confidence in the model results, calibration of the hydraulic model against two observed flood events and verification against two other observed flood events was undertaken. Hydrometric records from Gauge station 38026 at Sheering Hall (NGR 549530, 212705) were available to support the model calibration. This process followed the calibration of the hydrological model which is described in Section 4.3 of the hydrology report. Description of the selected events and associated hydrometric data is also provided in the hydrology report.

The gauging station consists of a flat V weir with the following parameters (data from 2015 Jacobs survey):

- 1: 8.680 cross-slope
- 3.93m breadth crest
- 44.95mAOD elevation of crest. (Note this is slightly below the reported EA crest level of 45.03 m AOD)

The hydraulic model was calibrated using the storm events with the highest observed peak water levels at the Sheering Hall gauge station in recent years, from 2011, since the tail water levels gauge was installed.

The events chosen for calibration are listed in Table 5 below:

Table 5 - Calibration and Verification events

Event	Date	Peak Head Water Level (mAOD)	Peak Tail Water Level (mAOD)	Comment
1	18/01/2011	46.391*	NA	Calibration
2	03/05/2012	46.517	46.529	Verification
3	20/12/2012	46.370	46.361	Verification
4	07/02/2014	46.426	46.464	Calibration

*Peak head and tail water levels were calculated using the gauge records plus the weir crest level as surveyed by Jacobs.

2.5.1 Calibration process

To enable a reliable hydraulic calibration, the model was truncated at its upstream extent at a cross section 175 m upstream of the level gauge. Observed flow hydrographs were then applied at the upstream end of the truncated model. The truncation ensured minimal or no flow was lost in the floodplain between the upstream end of the model and the gauge station and allowed modelled stage hydrographs to be directly compared with observed water levels.

Table 5 shows that at the peak of the events, the weir operated in drowned conditions, i.e. the downstream water level raised to a point affecting flow over the weir. This suggested that achieving a good fit between observed and modelled tail water levels was the starting point to achieve a good fit between observed and modelled head water levels.

The model was found to be not particularly sensitive to change in roughness. Roughness was increased by 40% downstream of the gauging station but this only produced a limited increase in tail water level (see Table 6).

Following inspection of the survey photographs, a restriction of cross section immediately downstream of the station was found and incorporated into the model (see Figure 7 top). No survey data was available for this cross section, so dimensions were estimated based uniquely on the

photograph below. However closely this cross section mimicked the channel geometry, the effect on tail water levels was still marginal (see Table 6).

A photograph taken during a January 2016 site visit (see Figure 7 bottom) shows a tree across a cross section located between the gauging station and the bridge on the B186. This suggested that the high tail water levels at the gauging station might have been the result of a temporary obstruction at a cross section downstream of the gauge. The obstruction was modelled by setting the Manning's "n" of cross sections PIN01_1925 - PIN01_1872 to 0.2. A good calibration between observed and modelled tail (see Table 6) and head water levels was then achieved (see also Appendix B). No other changes were deemed necessary. In particular, the calibration coefficient at the Flat-V weir was left equal to its default value of 1.

Section 1956.6 (Weir Section Looking Downstream)

Figure 7 - Pincey Brook photographs taken downstream of the gauging station

Table 6 - Calibration of peak tail water levels

Event	Tail Water Level (mAOD)				
	Observed	No changes made to the model	Incorporated restriction immediately downstream of gauge	Incorporated restriction immediately downstream of gauge + Roughness increased by 40% immediately downstream of gauge	Incorporated restriction immediately downstream of gauge + temporary obstruction
18/01/2011	NA	45.918	45.918	46.136	46.434
03/05/2012	46.529	45.866	45.868	46.076	46.412
20/12/2012	46.361	45.904	45.905	46.114	46.424
07/02/2014	46.464	45.780	45.785	46.000	46.374

2.5.2 Calibration results

Details of the calibration results are provided in Appendix B of this report. Tables comparing observed and modelled peak water levels are provided. Graphics showing modelled and observed level hydrographs at the gauge location are also provided. These results show that a satisfactory level of calibration was achieved across the four calibration/verification events with both observed and modelled tail and head water levels within +/- 125 mm of each other.

3. With-Scheme Modelling

Figure 8 shows the proposed features of the M11 Junction 7A scheme within the extent of the Pincey Brook and unnamed tributary model.

3.1 Hydrology Updates

The inflow locations along the Pincey Brook are the same for the proposed road scheme as for the Pincey Brook baseline scenario described in Section 2.3.2. The only impacts of the proposed road scheme on the Pincey Brook catchment hydrology are as follows:

(1) As shown in Figure 8, the B183 road alignment will provide a barrier to natural catchment runoff presently draining towards the Pincey Brook reach represented by inflow extent "Lateral 2". The small triangular catchment area represented by the hatched polygon in the plan will be diverted by a cut-off ditch into the catchment area discharging to inflow location PB4 (upstream of Lateral 2) to mitigate surface water flooding of the proposed road scheme. Hence, the catchment area draining to "Lateral 2" is decreased while the catchment area to PB4 is increased as a consequence of the proposed road scheme.

(2) The proposed attenuation ponds that are to discharge to the Pincey Brook are shown in blue on the plan in Figure 8. The discharge rates from the attenuation ponds will be restricted based on reduced existing discharge rates and/or greenfield runoff rates, and are insignificantly small compared to the flows in the Pincey Brook from a 52 km^2 catchment. Therefore no specific allowance was made for the proposed road runoff in the with-scheme inflow hydrographs.

Presented in Table 7 is a summary of the with-scheme peak inflows.

Table 7 - With-Scheme Flood Hydrograph Peak Inflows

Inflow Location	Easting (m)	Northing (m)	Annual Exceedance Probability (AEP)						
			50%	20%	5%	1%	1% (+35% CC)	1% (+70% CC)	0.1%
			Peak Inflows (m^3/s)						
PB1	550577	212953	5.56	7.84	10.79	14.41	19.45	24.49	33.12
PB2	550098	212846	0.24	0.34	0.47	0.63	0.84	1.06	1.45
PB3	549392	212177	0.10	0.14	0.19	0.25	0.34	0.43	0.59
Lateral 1	s. 549922 e. 549186	s. 212832 e. 212645	0.15	0.21	0.29	0.39	0.53	0.67	0.91
PB4	549078	212629	0.06	0.09	0.12	0.16	0.22	0.27	0.37
Lateral 2	s. 548988 e. 548112	s. 212557 e. 212796	0.12	0.17	0.23	0.31	0.41	0.52	0.71
s. = Start, e. = End, CC = Climate Change									

3.2 Hydraulic Model Updates

The following updates have been made to the 1D model to represent the road scheme features:

- The unnamed tributary downstream of The Mores has been completely realigned, with only one cross section (MOR01_0427 in the baseline model, renamed as MOR01_0545 in the with scheme model) being retained from the existing situation model.

- Typical cross section of the re-routed unnamed watercourse is trapezoidal, with a 1 in 1.5 bank side slopes.

- The same Manning's "n" roughness used for the river bed in the existing scenario was applied to the cross sections of the with-scheme model.

- The re-aligned unnamed tributary has two culverted sections under the proposed road embankments. The following details have been assumed for both culverts:
    - 2m by 2m box culverts;
    - Invert levels of the floor of the precast concrete box culverts are approximately 300mm below the invert levels of the watercourse either side;
    - Culvert inverts are sloped to centre to create a V- notch for lower flows;
    - To one side of each culvert there is a block forming an 'otter shelf' 300mm wide and 600mm high;
    - The same Manning's 'n' roughness used for the natural river bed has been utilised for the invert of the two culverts.

- No change was required to the modelled reach of Pincey Brook

In the 2D component of the model, the road scheme embankment has been incorporated to the model grid using the zshape tool available in TUFLOW.

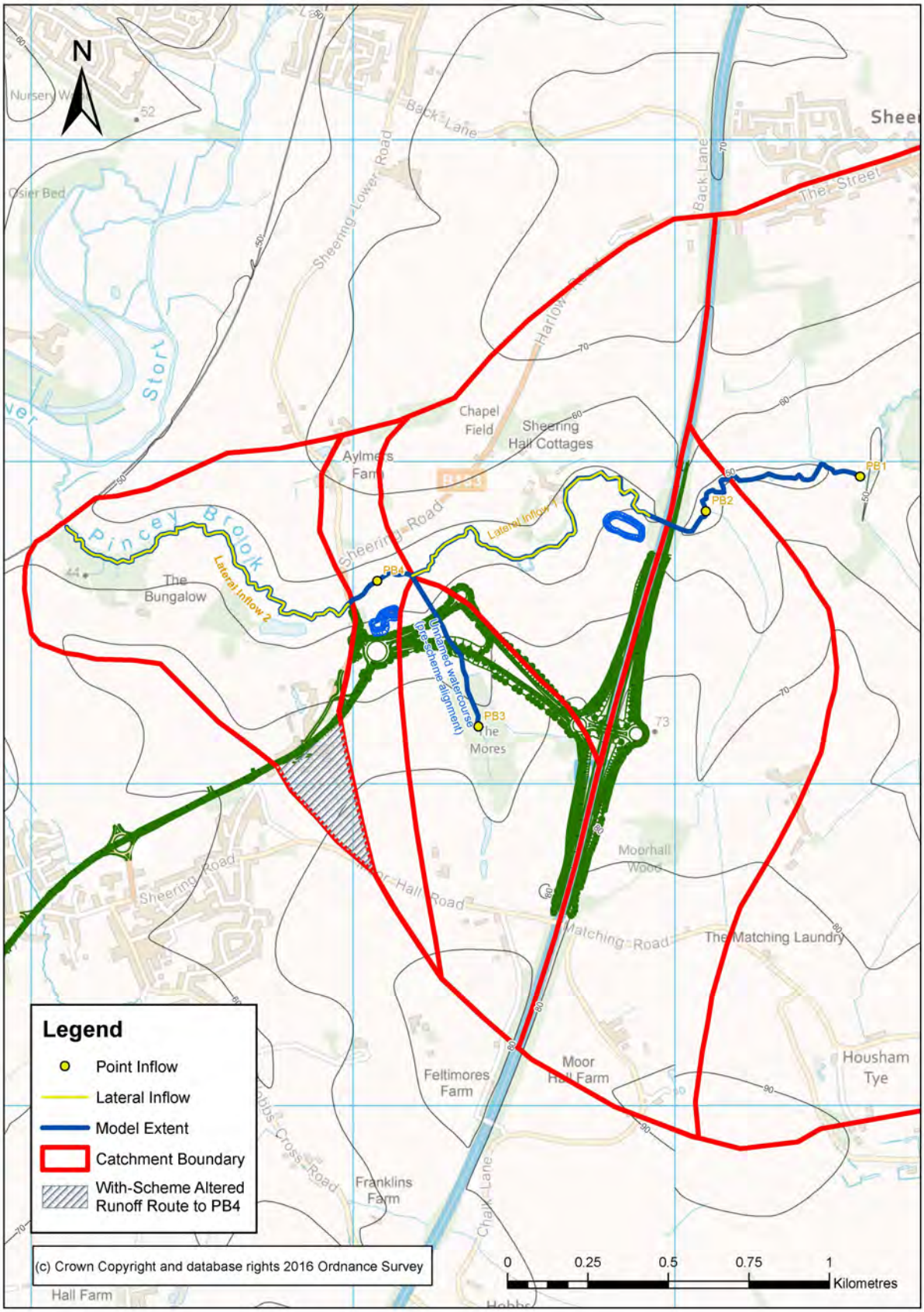


Figure 8 - With-scheme location plan

4. Modelled Design Events

Table 8 shows the AEP events and model scenarios that have been simulated with the hydraulic model. Baseline and with-scheme scenarios have been run for seven AEP events between the 50% and 0.1% AEP. A number of sensitivity runs were also carried out on key model parameters using the 1% AEP event. These assessed sensitivity to the Manning's "n" roughness coefficients, hydrological inflows, downstream boundary conditions and structures coefficients.

Table 8 - Modelled events

Reach	Scenario	AEP Event						
		50%	20%	5%	1%	1% (+35% CC)	1% (+70% CC)	0.1%
Pincey Brook and Unnamed Tributary	Baseline	✓	✓	✓	✓	✓	✓	✓
	With-Scheme	✓	✓	✓	✓	✓	✓	✓
	Roughness Sensitivity				✓			
	Inflow Sensitivity				✓			
	Downstream Sensitivity				✓			
	Structure coefficient Sensitivity				✓			

5. Model Results

5.1 Baseline scenario

Results from the baseline modelling are presented below with tabulated peak water levels available in Appendix A. Maximum Flood depths for the 1% AEP event are presented in Figure 9 and flood extents for all simulated events are presented in Figure 10 and Figure 11.

5.1.1 Flood mechanisms

The modelled river channel has a high sinuosity and the channel capacity is largely exceeded in flood events larger than the 50% AEP. Once out of bank flows follow a more direct route as defined by the topographic level contours with flood widths generally less than 100 m during a 1% AEP flood event.

The baseline model results show flooding in the early part of the storm as caused by the flow constrictions at of a number of river crossing structures most notably the railway line culvert and B183 road bridge. Capacity of the railway culvert is exceeded during a 50% AEP event and consequently significant ponding of flood water is predicted upstream of the railway line. Further upstream, the B183 road bridge also acts as a significant flow constriction and water is predicted to pond upstream of the road embankment. Neither embankment is predicted to be overtopped during a 1% AEP event but the B183 road embankment is predicted to be overtopped during a 0.1% AEP event.

Flow in The Mores watercourse exceeds the culvert capacity that connects it to Pincey Brook under all the events modelled and most of the catchment flows run overland from the culvert inlet down to Pincey Brook. The area around the culvert inlet is relatively flat and there is no significant flood storage in this area as a result of the low culvert capacity.

In Pincey Brook, upstream of The Mores confluence, the floodplain is most extensive to the south of Sheering Hall with the model predicting out of bank flows on both sides of the river creating a flood width of 200 m. Flooding on the right bank is predicted to inundate a few properties south of Sheering Hall. Also to the south of Sheering Hall is the river gauging station, model results here show some out of bank flows at the gauge location under most return periods.

Upstream of Sheering Hall the floodplain is confined to an area approximately 50 m either side of the channel as it passes under the M11. The two culverts under the M11 are predicted to convey flows up to and including the 1% AEP plus climate change (+35%).

With the exception of the areas upstream of the B183 road and Railway crossing, floodplain flood depth are less than 1 m and velocities in the floodplain are generally less than 0.5m/s.

All the areas predicted to be inundated by the model are either pasture land, arable land or scrub/ wooded areas, with the exception of the properties at Sheering Hall.

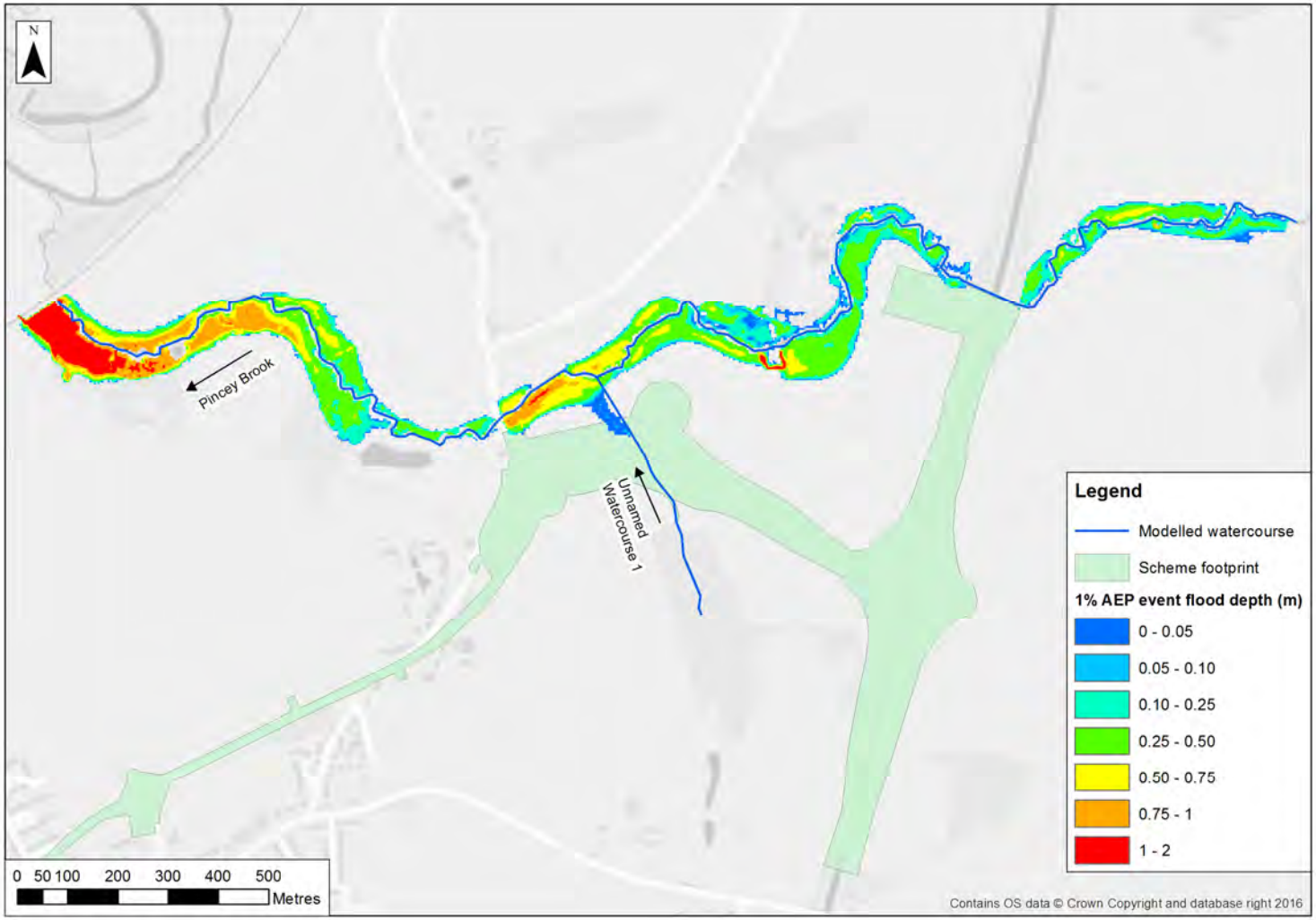


Figure 9 - 1% AEP maximum flood depths predicted by the hydraulic model

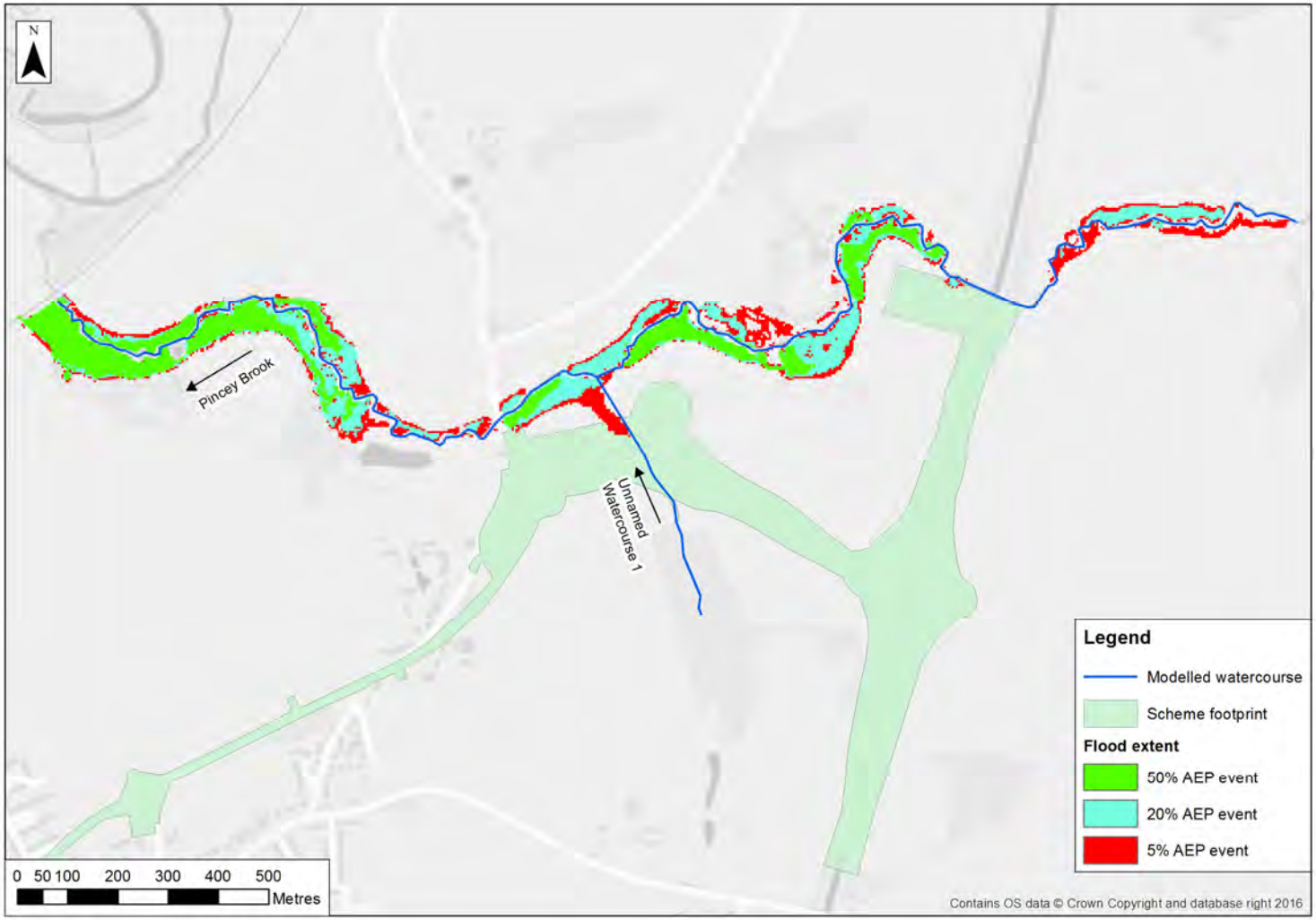


Figure 10 – 50%, 20%, 5% AEP maximum flood extents predicted by the hydraulic model

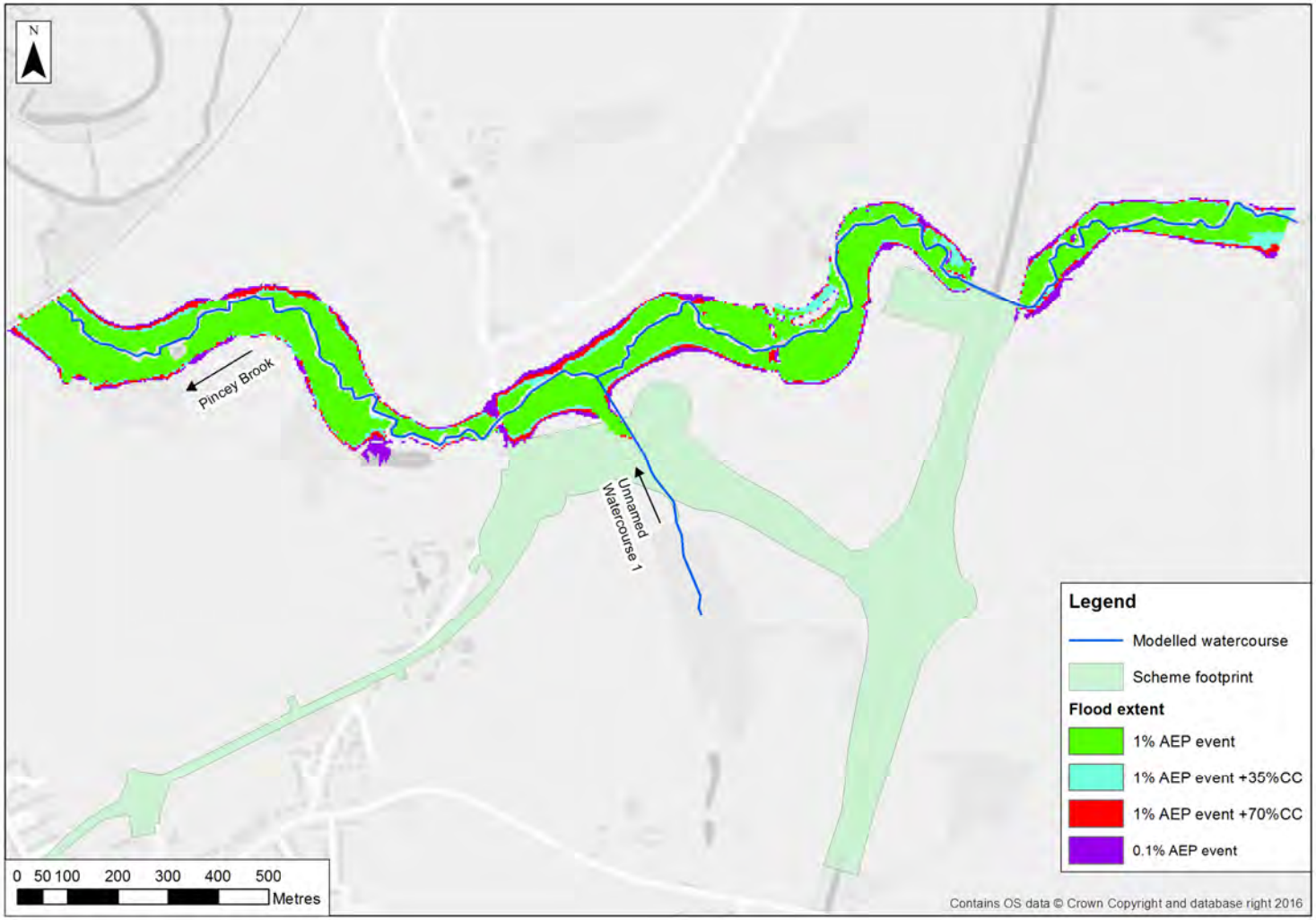


Figure 11 - 1%, 1% CC (+35% and +70%), 0.1% AEP maximum flood extents predicted by the hydraulic model

5.1.2 Environment Agency Flood Zone Comparison

Figure 12 shows the modelled 1% AEP existing situation flood extent predicted by the baseline model and the Environment Agency published Flood Zone 3. Figure 13 shows the modelled 0.1% AEP existing situation flood extent and the Environment Agency published Flood Zone 2.

It is believed that the published Flood Zones are the combined output from the 2007 Faber Maunsell Infoworks RS model and the 2010 Halcrow combined ISIS/Tuflow model.

In general modelled flood extents are in agreement with the published flood zones.

In the area from the unnamed tributary to the railway culvert Flood Zone 2 and 3 look generally wider than the flood extents generated from the current baseline model. The following reasons for these discrepancies have been identified:

- Hydrology for the present study and for the two 2007 Infoworks RS model is different.
- The schematisation of the area of interest in the current baseline model is believed to be finer than in the 2007 Infoworks model as it has used a 2D modelling approach and LiDAR data to represent the floodplain areas.

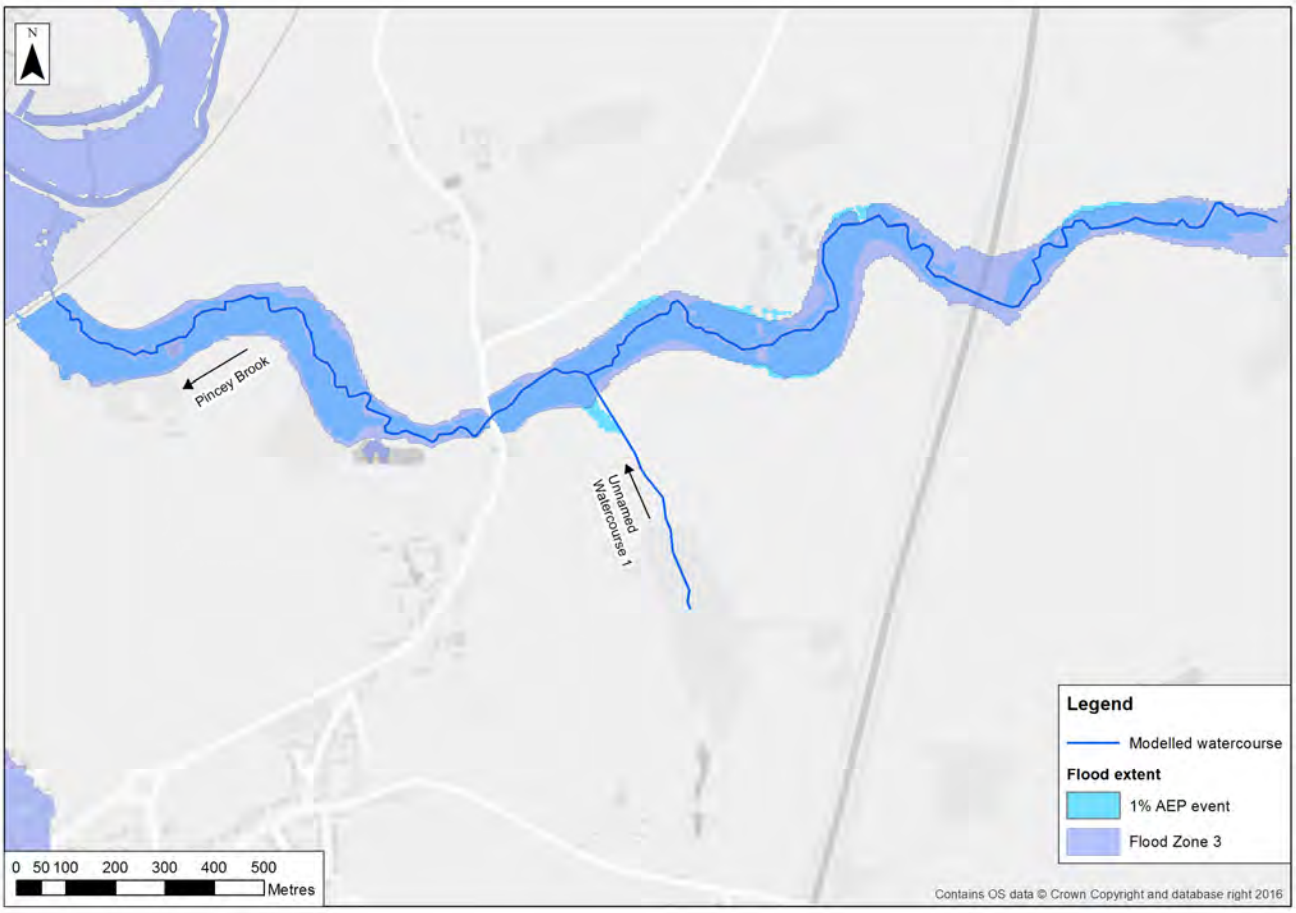


Figure 12 - Modelled 1% AEP flood extent and Environment Agency Flood Zone 3

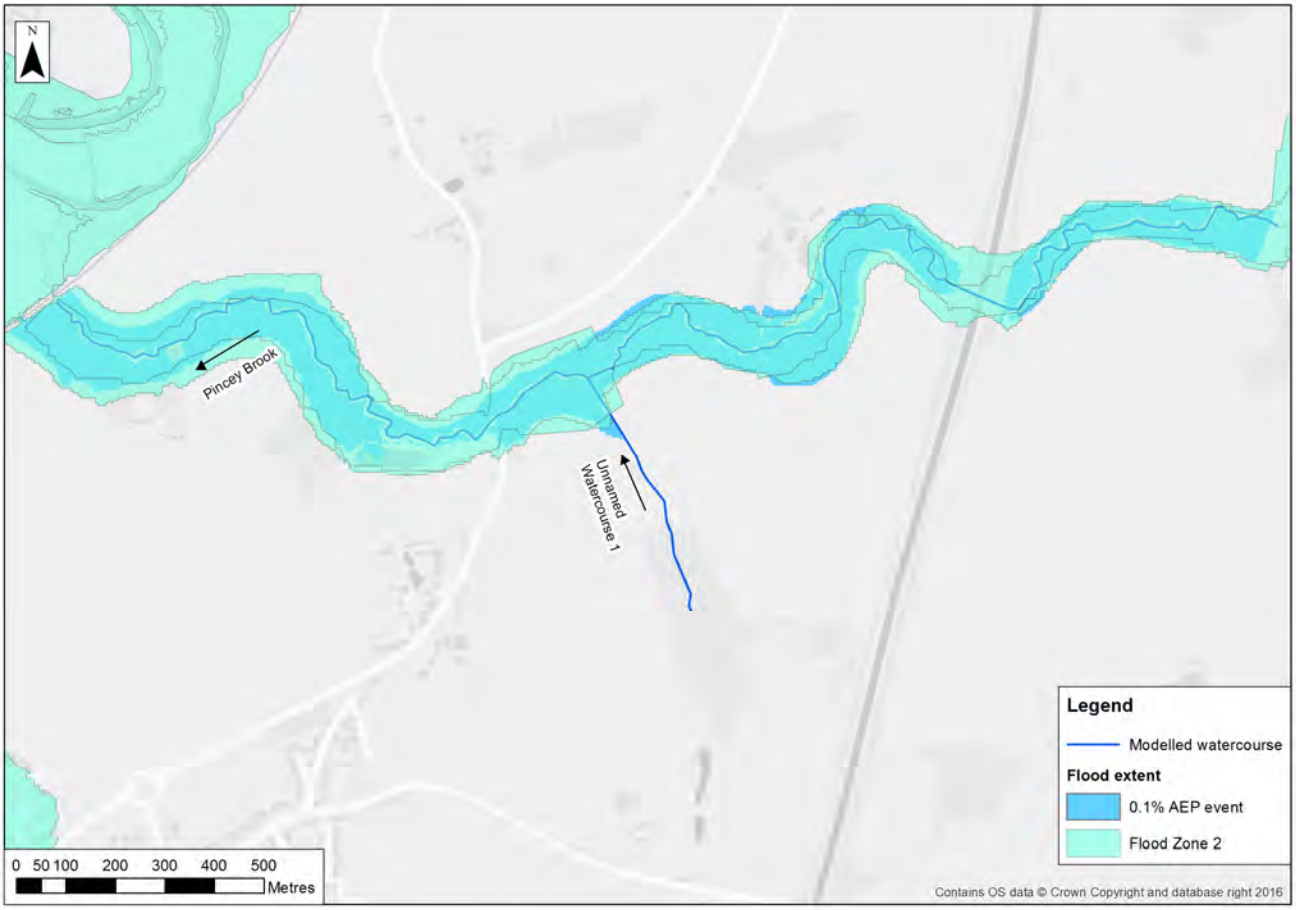


Figure 13 - Modelled 0.1% AEP flood extent and Environment Agency Flood Zone 2

5.1.3 Sensitivity analysis

Sensitivity tests were carried out for the 1% AEP event to assess the model response to adjustment of:

- Hydrological inflows: Model inflows changed by +20% and -20%.
- Roughness: In-channel and floodplain roughness coefficient (Manning's "n") changed by +20% and -20%.
- Downstream boundary: Normal depth boundary gradient changed by +20% and -20%.

Structures producing large headlosses (>100mm) and believed to be critical for the scheme were also considered. These critical structures were identified as the Sheering Hall access bridge (node PIN01_2272wu in the FM model) and the Ealing Bridge (node PIN01_1278bu). Surcharged flow coefficients at these structures were varied by +20% and -20%.

Sensitivity analysis was also carried out on the dimensions of the railway culvert (node PIN01_0000), to reduce the uncertainties associated to this unsurveyed structure (see Section 2.3.4). Dimensions of the culvert were changed to produce an increase/decrease of area by 20%.

Table 9 shows the changes to in-channel water level relative to the existing situation model for each sensitivity test at several locations in the vicinity of the scheme.

It can be seen that peak water levels in Pincey Brook are moderately sensitive to hydrological flows and hydraulic roughness. Variations above the baseline peak water levels range from +/-100mm to +/-200mm. Model results for the unnamed tributary show very little sensitivity to changes in roughness and flows. Figure 14 shows the changes in flood extent as a result of the roughness sensitivity testing. Figure 15 shows the changes in flood extent as a result of the flow sensitivity testing.

Table 9 also shows that the predicted peak water levels in Pincey Brook and the unnamed tributary are not sensitive to the other changes described above i.e. structure coefficients and downstream conditions.

In summary the model results are considered robust and reliable to the standard uncertainties associated with hydraulic modelling.

Table 9 - Sensitivity test results - 1% AEP peak water levels

Watercourse	Cross section	Model	Peak Water Level (mAOD)	Difference (m)
Pincey Brook	PIN01_1533	Baseline	45.993	
		+20% Flow	46.187	0.194
		-20% Flow	45.816	-0.177
		+20% Roughness	46.098	0.105
		-20% Roughness	45.880	-0.113
		+20% Downstream boundary gradient	45.993	0
		-20% Downstream boundary Gradient	45.993	0
		+ 20% Surcharged flow coefficient at PIN01_2272wu	45.993	0
		- 20% Surcharged flow coefficient at PIN01_2272wu	45.993	0
		+20% Orifice discharge coefficient at PIN01_1278bu	45.966	-0.027
		-20% Orifice discharge coefficient at PIN01_1278bu	46.064	0.071
		+20% Area of railway culvert	45.993	0
		- 20% Area of railway culvert	45.993	0
Pincey Brook	PIN01_1278	Baseline	45.862	
		+20% Flow	46.065	0.203
		-20% Flow	45.673	-0.189
		+20% Roughness	45.967	0.105
		-20% Roughness	45.753	-0.109
		+20% Downstream boundary gradient	45.862	0
		-20% Downstream boundary Gradient	45.862	0
		+ 20% Surcharged flow coefficient at PIN01_2272wu	45.862	0
		- 20% Surcharged flow coefficient at PIN01_2272wu	45.862	0
		+20% Orifice discharge coefficient at PIN01_1278bu	45.824	-0.038
		-20% Orifice discharge coefficient at PIN01_1278bu	45.958	0.096
		+20% Area of railway culvert	45.862	0
		- 20% Area of railway culvert	45.862	0
Unnamed tributary at the Mores	MOR01_0277	Baseline	51.842	
		+20% Flow	51.869	0.027
		-20% Flow	51.814	-0.028

Watercourse	Cross section	Model	Peak Water Level (mAOD)	Difference (m)
		+20% Roughness	51.868	0.026
		-20% Roughness	51.815	-0.027
		+20% Downstream boundary gradient	51.842	0
		-20% Downstream boundary Gradient	51.842	0
		+ 20% Surcharged flow coefficient at PIN01_2272wu	51.842	0
		- 20% Surcharged flow coefficient at PIN01_2272wu	51.842	0
		+20% Orifice discharge coefficient at PIN01_1278bu	51.842	0
		-20% Orifice discharge coefficient at PIN01_1278bu	51.842	0
		+20% Area of railway culvert	51.842	0
		- 20% Area of railway culvert	51.842	0
Unnamed tributary at the Mores	MOR01_0126	Baseline	48.572	
		+20% Flow	48.588	0.016
		-20% Flow	48.558	-0.014
		+20% Roughness	48.583	0.011
		-20% Roughness	48.566	-0.006
		+20% Downstream boundary gradient	48.572	0
		-20% Downstream boundary Gradient	48.572	0
		+ 20% Surcharged flow coefficient at PIN01_2272wu	48.572	0
		- 20% Surcharged flow coefficient at PIN01_2272wu	48.572	0
		+20% Orifice discharge coefficient at PIN01_1278bu	48.572	0
		-20% Orifice discharge coefficient at PIN01_1278bu	48.572	0
		+20% Area of railway culvert	48.572	0
		- 20% Area of railway culvert	48.572	0

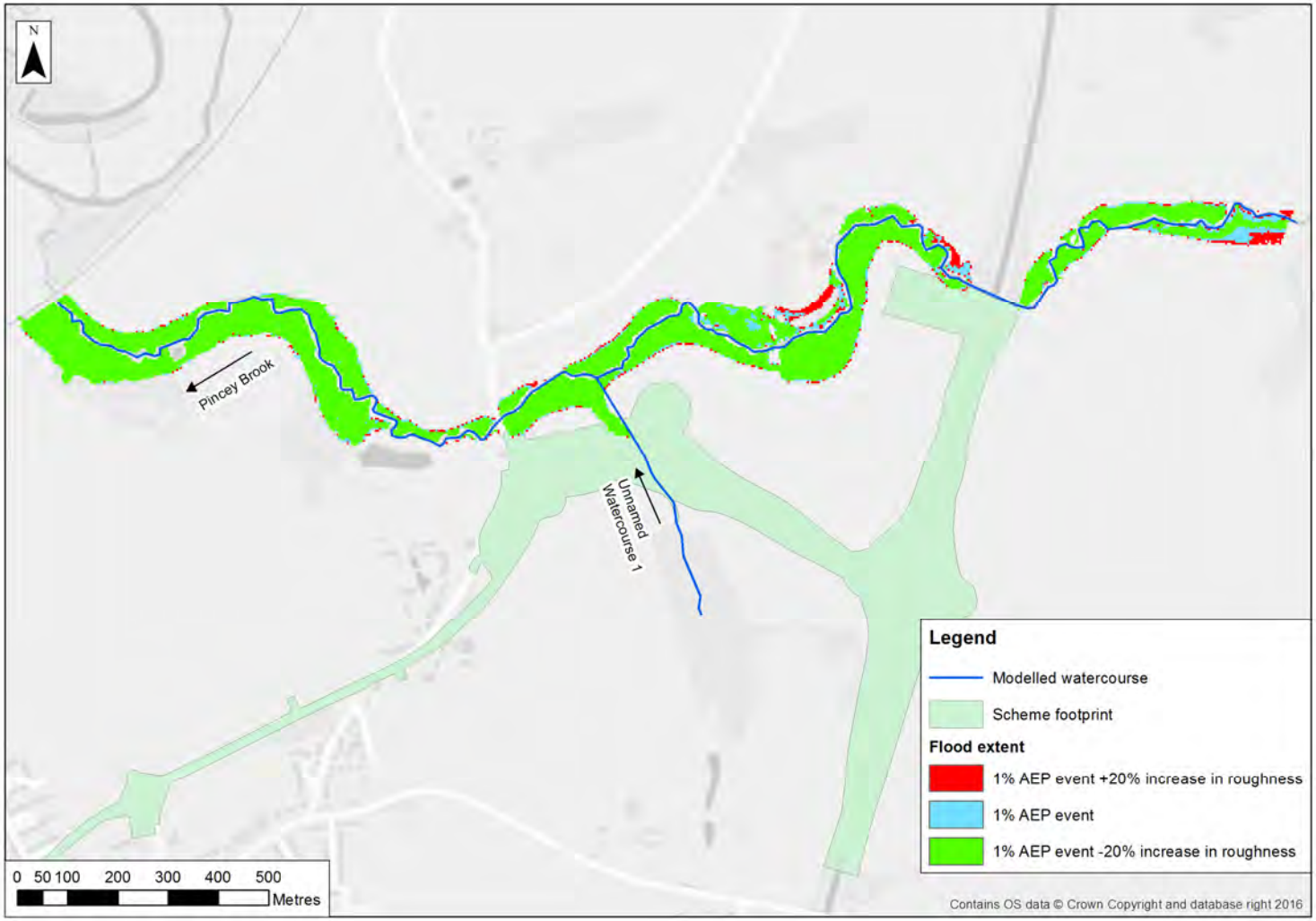


Figure 14- Sensitivity to roughness - 1% AEP Flood extent

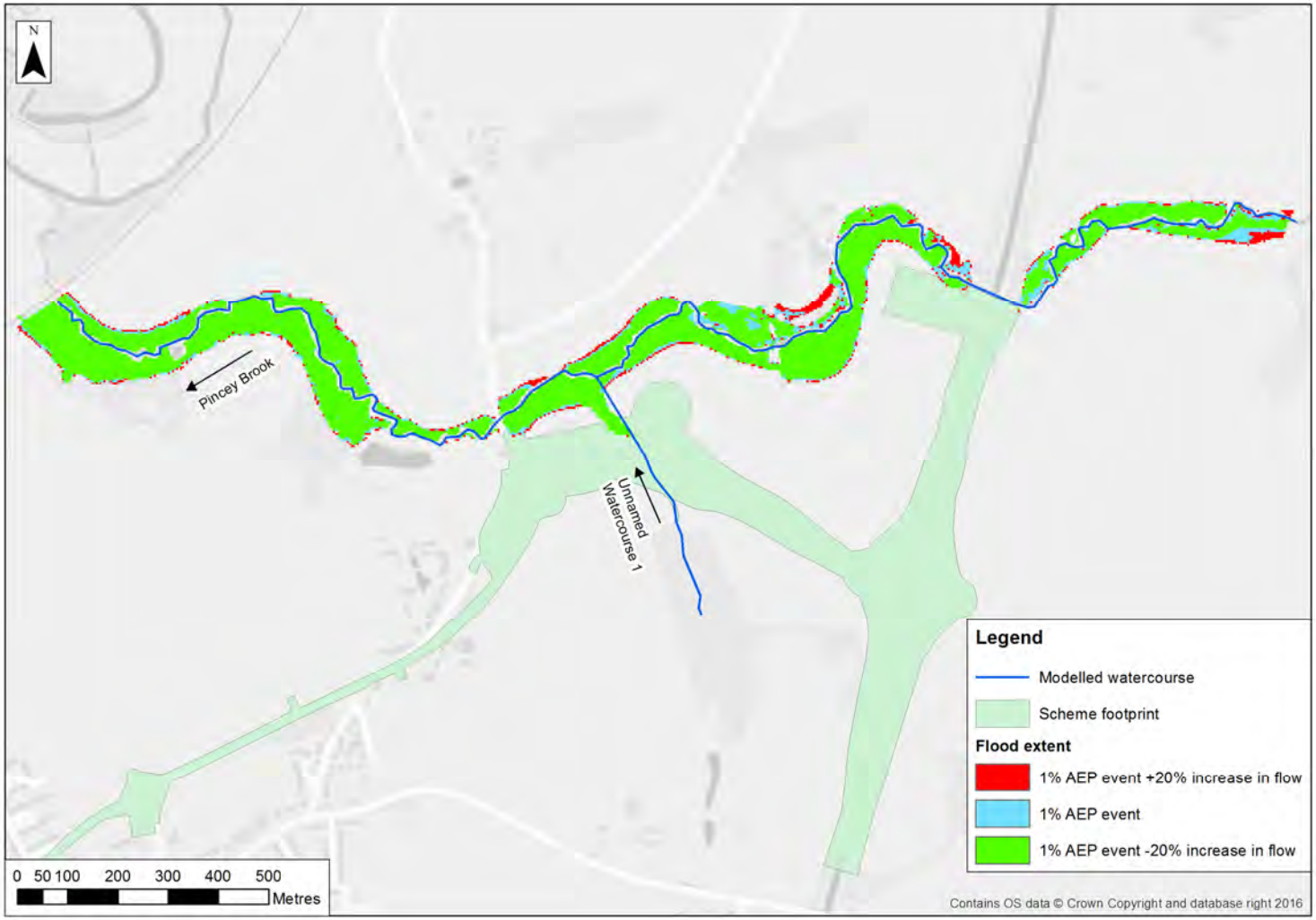


Figure 15 - Sensitivity to hydrological inflows - 1% AEP flood extent

5.2 Effect of proposed scheme

The results of the with-scheme modelling are presented below with tabulated peak water levels available in Appendix A.

To assess the impact of the proposed scheme on the existing flood risk, in-channel water level outputs extracted for the baseline situation were compared to the with-scheme situation models at key locations. These are presented in Table 10.

The unnamed tributary was diverted so a direct comparison between with-scheme and baseline model was not possible.

Table 10 - Peak water levels difference (With-scheme - Baseline) along Pincey Brook

Watercourse	Cross Section	Maximum water level difference (m)						
		50% AEP	20% AEP	5% AEP	1% AEP	1% AEP +35%CC	1% AEP +70%CC	0.1% AEP
Pincey Brook	PIN01_1627	-0.004	-0.002	0.000	-0.001	0.001	0.003	0.024
	PIN01_1533	-0.005	-0.003	-0.001	-0.001	0.001	0.004	0.024
	PIN01_1520u	-0.005	-0.004	0.000	-0.001	0.001	0.003	0.025
	PIN01_1520d	-0.005	-0.004	0.000	-0.001	0.001	0.003	0.025
	PIN01_1482	-0.003	-0.004	0.000	-0.002	0.001	0.003	0.025
	PIN01_1404u	-0.001	-0.006	0.000	-0.001	0.002	0.004	0.025
	PIN01_1404d	-0.001	-0.006	0.000	-0.001	0.002	0.004	0.025
	PIN01_1330	0.001	-0.002	0.000	-0.002	-0.001	0.003	0.024
	PIN01_1278	0.000	0.000	0.001	-0.001	0.000	0.003	0.022
	PIN01_1278d	0.000	0.000	0.001	-0.001	0.000	0.000	0.000
	PIN01_1270	0.000	0.000	0.001	-0.001	0.000	0.001	-0.002
	PIN01_1199	0.000	0.001	0.001	-0.001	0.000	0.001	0.000

As Table 10 above highlights there is no significant change to in-channel peak water levels as a result of the scheme design modelled.

The modelled hydrology is basically unchanged as any additional runoff associated with the scheme is being attenuated based on reduced existing discharge rates and/or greenfield runoff rates via attenuation ponds, and as such there is no significant change to the baseline hydrology. In addition the scheme requires no changes to Pincey Brook channel structures and with the exception of a slight increase in the embankment width at the B183 crossing there is no development within the modelled floodplain. Consequently we see no adverse effects of the scheme in the results of either the 1D or 2D modelling.

Figure 16 and Figure 17 show the 1% AEP flood extents for the 1% and 0.1% AEP with-scheme modelling and Figure 18 and Figure 19 show the depth comparison between baseline and scheme for the 1% AEP and 1% AEP plus 35% climate change events. The difference map highlights that there is no significant difference between the two depth grids (less than ±0.01 m difference is classed as negligible, see Table 11) indicating the scheme has no impact on floodplain flooding with the exception of the unnamed watercourse at the Mores and the small area of embankment on the B183 crossing. In the unnamed watercourse the existing overland flow that occurs as a result of the culvert capacity has been removed and all flood flows are now conveyed in a new channel draining into Pincey Brook just downstream of the existing outfall/ overland flow path. The relocation of this inflow is not predicted to have any significant impact on peak water levels except to the immediate confluence area and as shown in Figure 18 this is not predicted to impact flood extents at all. The removal of the existing culvert draining the tributary and replacement with an open channel and culvert including mammal passage is considered to improve the overall hydraulics and nature of the watercourse.

No adverse impacts are predicted up to and including a 1% AEP plus 70% climate change and the scheme is also predicted to be flood free up to and including the 0.1% AEP event.

A Long section of the 1D river model results for the 1% AEP event for Pincey Brook are presented in Figure 20 showing a comparison between peak in-channel water levels predicted by the baseline model and with-scheme model.

Table 11 - Categorisation of difference in flood depths

	Potential Flood Impact	Criteria	Flood Risk
	Major Adverse	Results in loss of attribute and/ or quality and integrity of the attribute	Increase in peak flood depth >100 mm
	Moderate Adverse	Results in effect on integrity of attribute, or loss of part of attribute	Increase in peak flood depth 50-100 mm
	Minor Adverse	Results in some measurable change in attributes quality or vulnerability	Increase in peak flood depth 10-50 mm
	Negligible	Results in effect on attribute, but of insufficient magnitude to affect the use or integrity	Negligible change in peak flood depth <+/- 10 mm
	Minor Beneficial	Results in some beneficial effect on attribute or a reduced risk of negative effect occurring	Reduction in peak flood depth 10-50 mm
	Moderate Beneficial	Results in moderate improvement of attribute quality	Reduction in peak flood depth 50-100 mm
	Major Beneficial	Results in major improvement of attribute quality	Reduction in peak flood depth >100mm

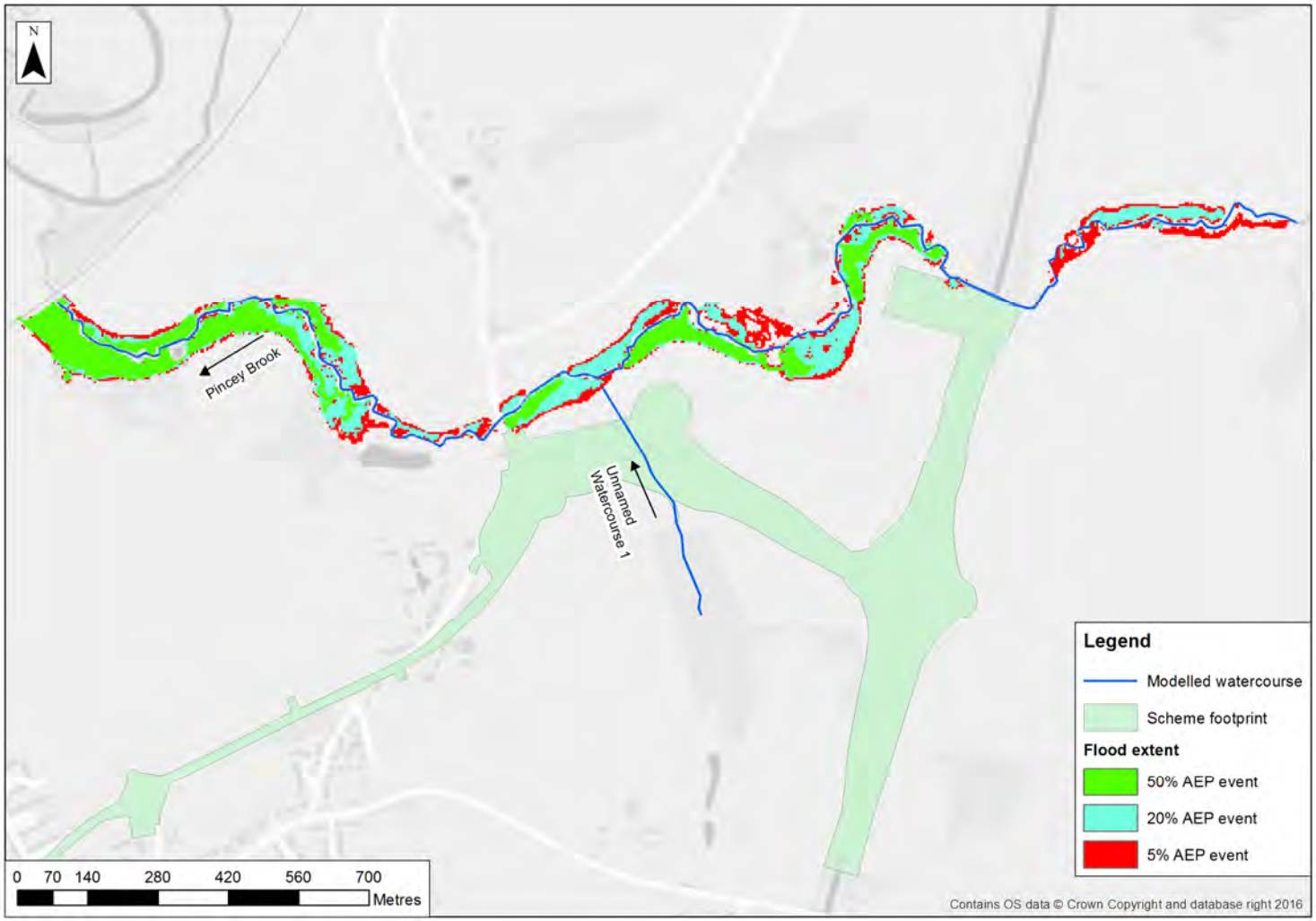


Figure 16 - With Scheme 50%, 20%, 5% AEP maximum flood extents predicted by the hydraulic model

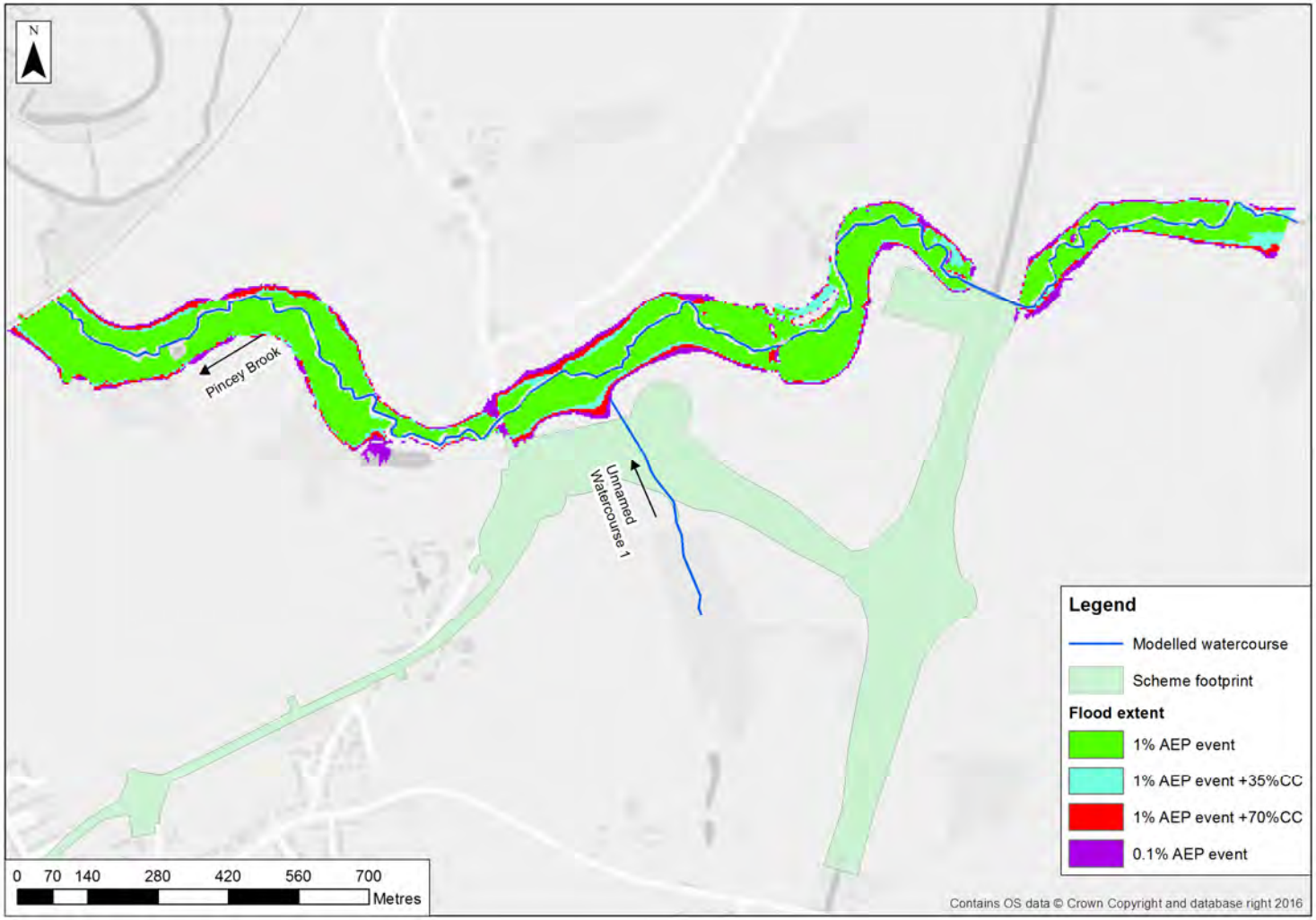


Figure 17 – With Scheme 1%, 1% CC (+35% and +70%), 0.1% AEP flood extents

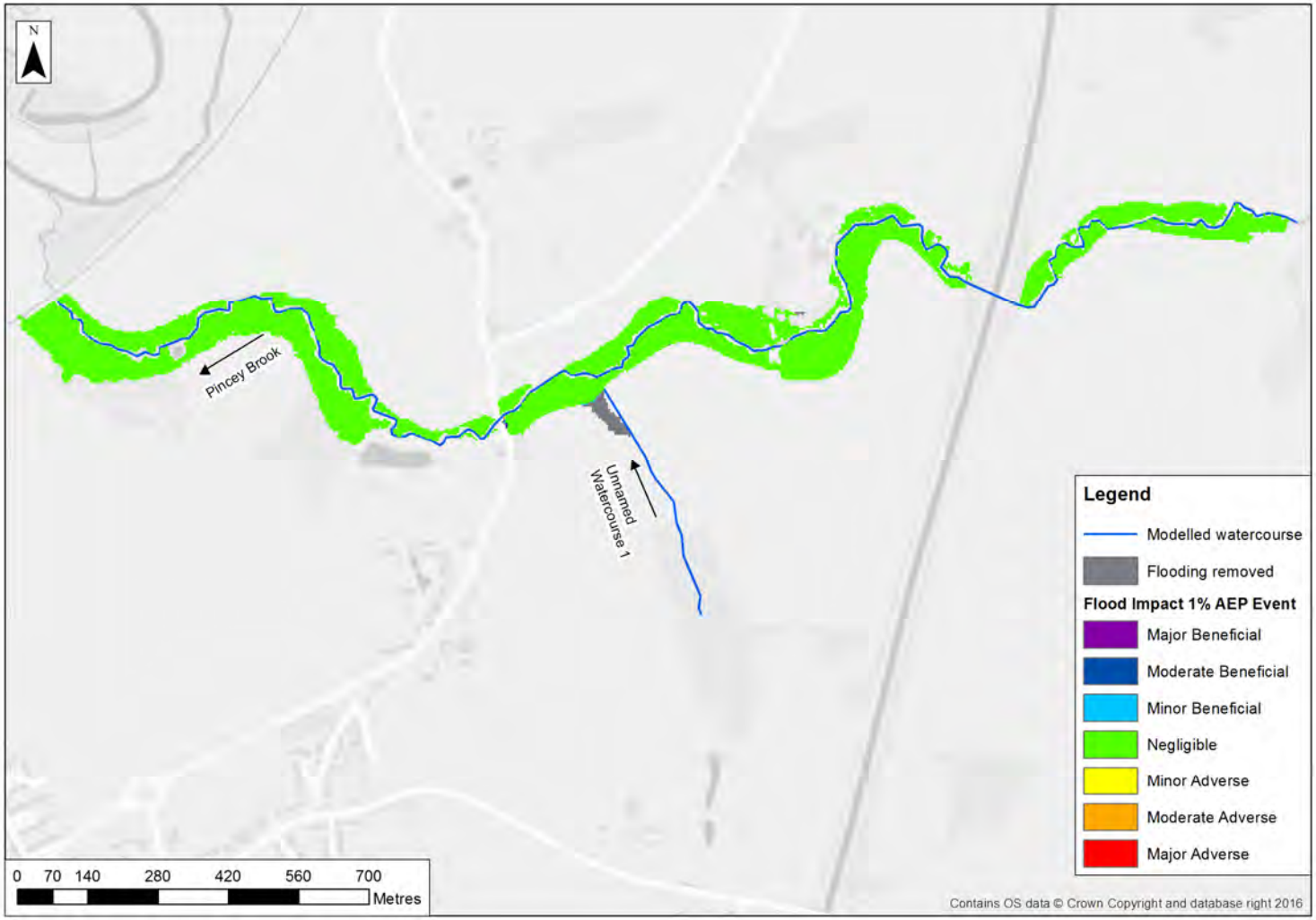


Figure 18 – Depth Difference Baseline Minus Scheme 1% AEP

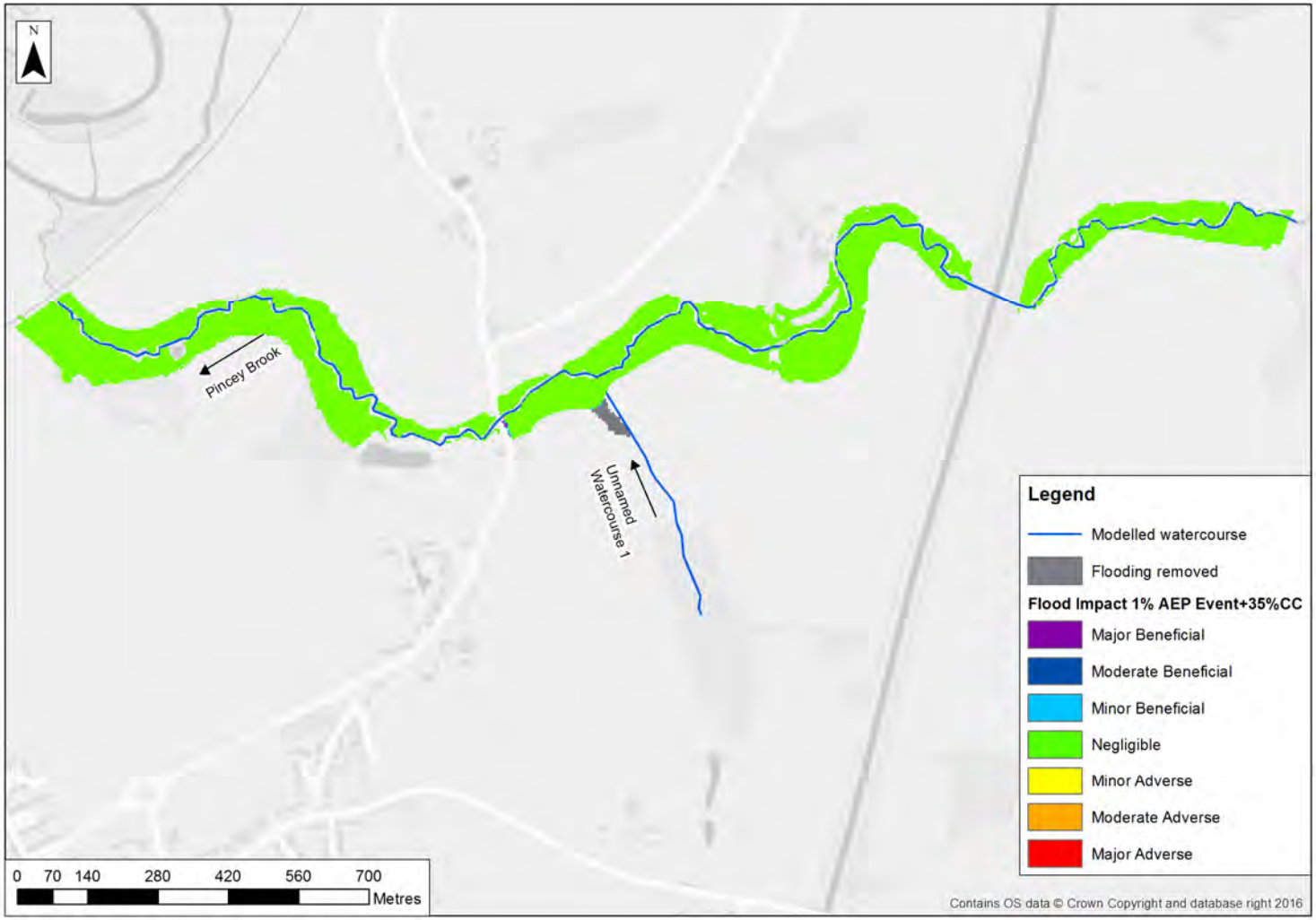


Figure 19 – Depth Difference Baseline Minus Scheme 1% AEP plus 35% Climate Change

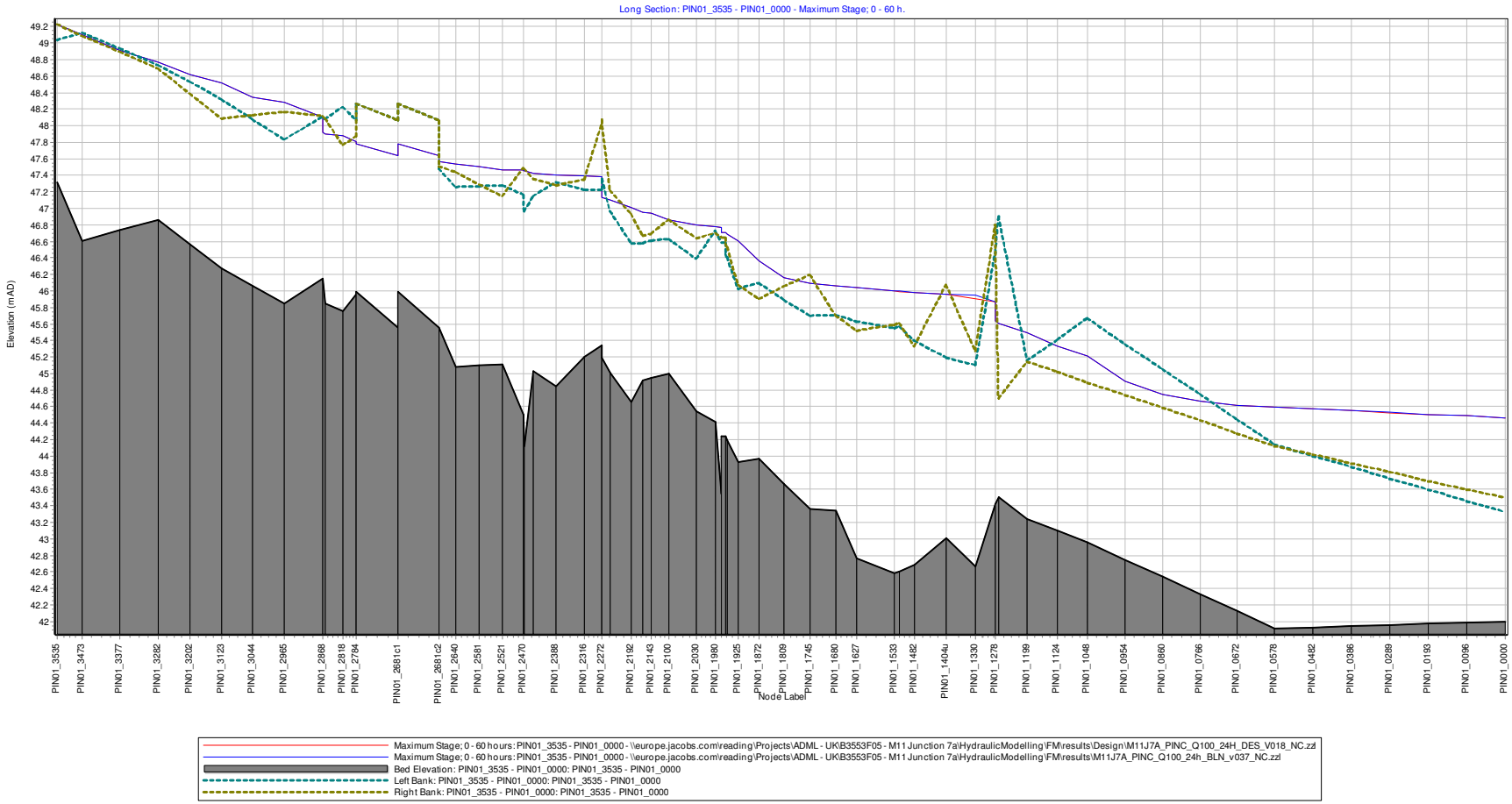


Figure 20 – Long Section Model Results for a 1% AEP flood event

6. Key model assumptions and limitations

Standard assumptions and limitations associated with hydraulic modelling are applicable to this study including the following;

- Model results are dependent on the hydrological uncertainty as outlined in the hydrology report[6]
- The results of the flood extent and depths are limited to the accuracy of the LiDAR data
- Flood extents upstream of the railway line are subject to some uncertainty as the structure dimensions have not been surveyed

[6] M11 Junction 7A, Pincey Brook Design Flood Hydrology, Jacobs, 2016

7. Conclusions

This hydraulic modelling study has been undertaken to support the development of a new motorway junction (Junction 7A) on the M11 between existing Junctions 7 and 8 including a proposed link road to Sheering Road (B183).

A detailed hydrological study has been undertaken to provide inflows to both a Baseline and With-scheme hydraulic model.

A 1D 2D hydraulic model of the Pincey Brook has been constructed using Flood Modeller (1D) and Tuflow (2D) and run as dynamically link 1D/2D flood model. The Baseline model has been run for seven AEP events between the 50% and 0.1% AEP. In addition the baseline model has been validated against water level records from the Gauge station 38026 at Sheering Hall. Four recorded flooded events were modelled dating back to 2011. The results showed a satisfactory level of calibration was achieved across the four calibration/verification events with both observed and modelled tail and head water levels within +/- 125 mm of each other.

The road design was included into the model to create a With-Scheme scenario and run for the same seven AEP events as the baseline using the revised hydrology.

The results from the modelling indicate that the scheme has no significant impact on the existing flood risk under all the events modelled. The modelled hydrology is basically unchanged as any additional runoff associated with the scheme is being attenuated based on reduced existing discharge rates and/or greenfield runoff rates via attenuation ponds, and as such there is no significant change to the baseline hydrology. In addition the scheme requires no changes to Pincey Brook channel structures and with the exception of a slight increase in the embankment width at the B183 road crossing there is no development within the modelled floodplain. Consequently the modelling does not predict any adverse effects as a result of the scheme.

Appendix A. Baseline Model reference files

1D domain	
DAT file	M11J7A_PINC_BLN_v037.DAT
ied files	PB_Des_2yr_24h.IED
	PB_Des_5yr_24h.IED
	PB_Des_20yr_24h.IED
	PB_Des_100yr_24h.IED
	PB_Des_100yrCC35p_24h.IED
	PB_Des_100yrCC70p_24h.IED
	PB_Des_1000yrp_24h_v2.IED
ief files	M11J7A_PINC_Q2_24h_BLN_v037.ief
	M11J7A_PINC_Q5_24h_BLN_v037.ief
	M11J7A_PINC_Q20_24h_BLN_v037.ief
	M11J7A_PINC_Q100_24h_BLN_v037.ief
	M11J7A_PINC_Q100CC35p_24h_BLN_v037.ief
	M11J7A_PINC_Q100CC70p_24h_BLN_v037.ief
	M11J7A_PINC_Q1000_24h_BLN_v037.ief
2D domain	
tcf files	M11J7A_PINC_Q2_24h_BLN_v037.tcf
	M11J7A_PINC_Q5_24h_BLN_v037.tcf
	M11J7A_PINC_Q20_24h_BLN_v037.tcf
	M11J7A_PINC_Q100_24h_BLN_v037.tcf
	M11J7A_PINC_Q100CC35p_24h_BLN_v037.tcf
	M11J7A_PINC_Q100CC70p_24h_BLN_v037.tcf
	M11J7A_PINC_Q1000_24h_BLN_v037.tcf
tbc file	M11_J7A_v011.tbc
tgc file	M11_J7A_v011.tgc
Material file	M11_J7A_v002.tmf

All model run time parameters were set to their default values, with the exception of the use of the automated Preissman slot option, which improve model stability by preventing the channel from running dry.

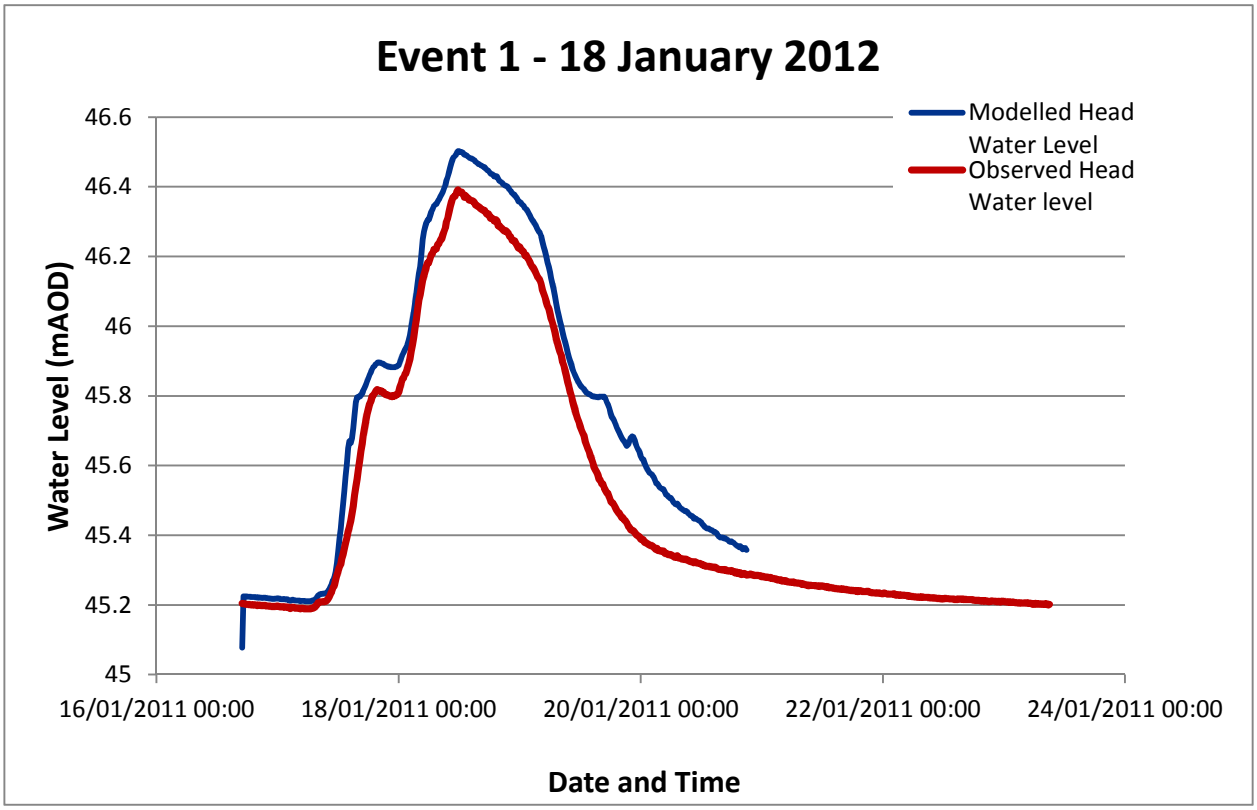
Baseline and Scheme model was run with a 1D timestep = 1sec and a 2D timestep = 1sec, The run time parameters used are summarised below.

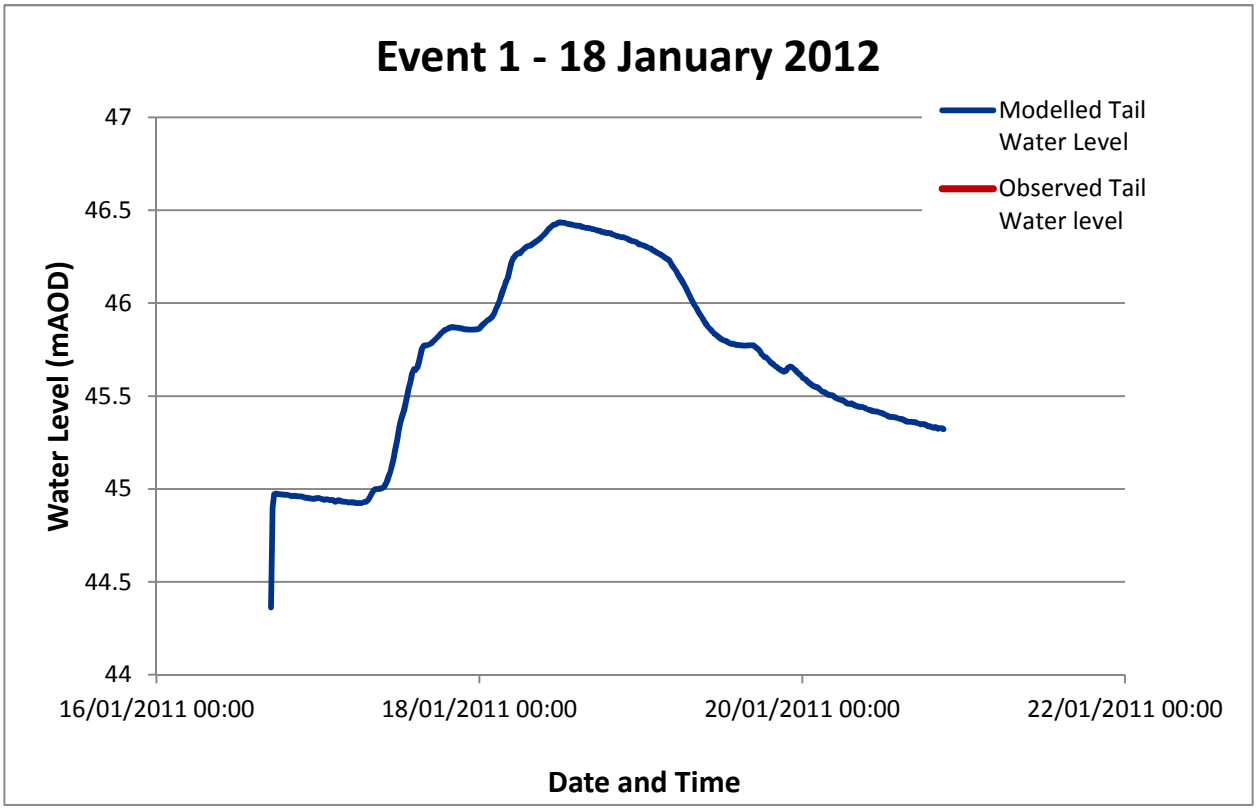
Description	Value used
Initial conditions	From DAT file
Use of ied files	Yes
Run Type	Unsteady (Fixed timestep)
Start Time (hrs)	0
End Time (hrs)	60
Automated Preissmann slot for river sections	Yes
Parameters	Default
Advanced Parameters	Default

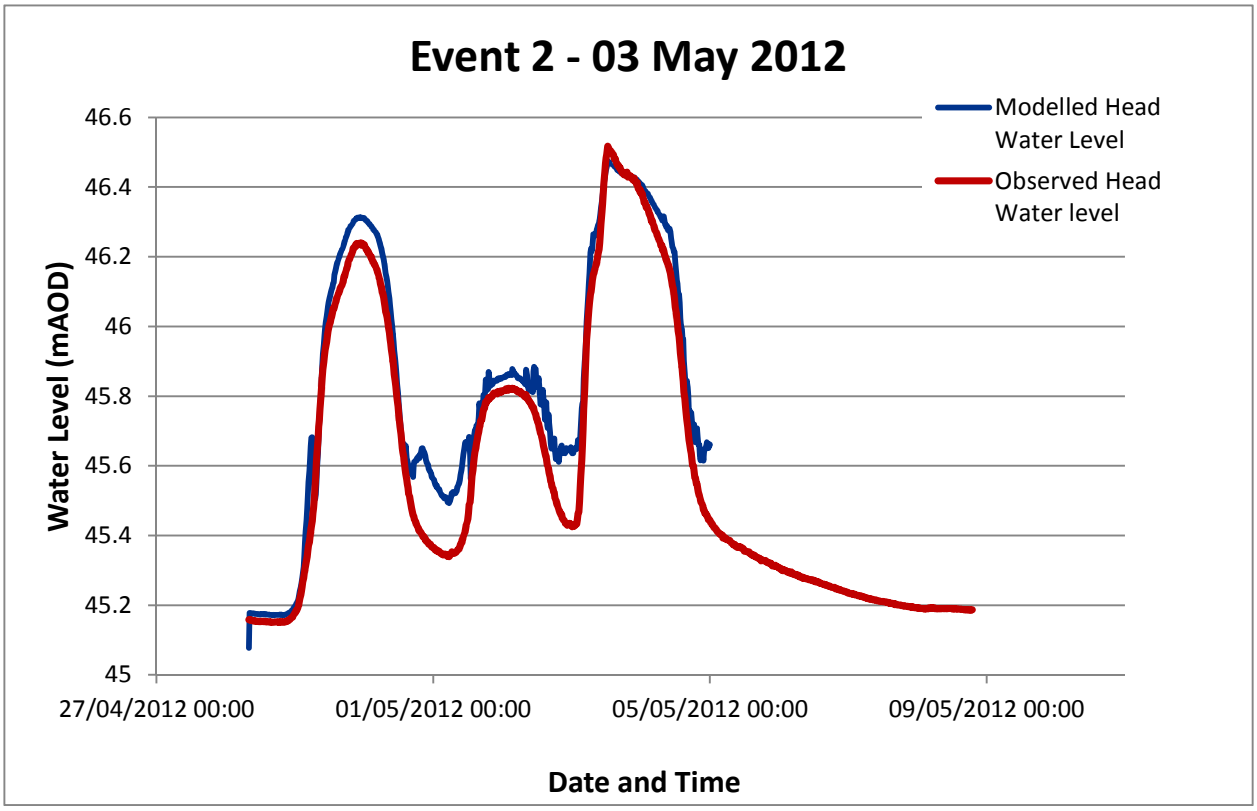
Appendix B. Hydraulic model calibration results

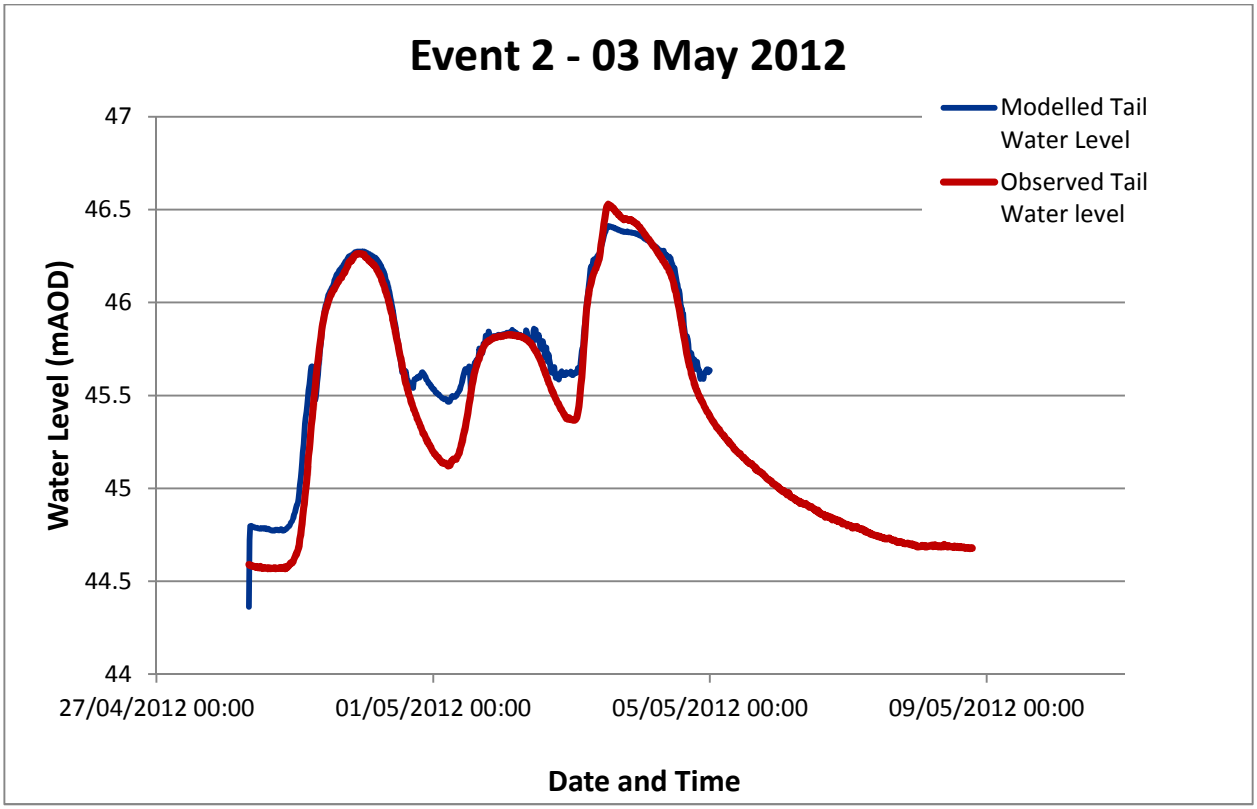
Event	Tail water levels (mAOD)		Difference (m)
	Observed	Modelled	
18/01/2011	NA	46.434	-
03/05/2012	46.529	46.412	-0.117
20/12/2012	46.361	46.424	0.063
07/02/2014	46.464	46.374	-0.090

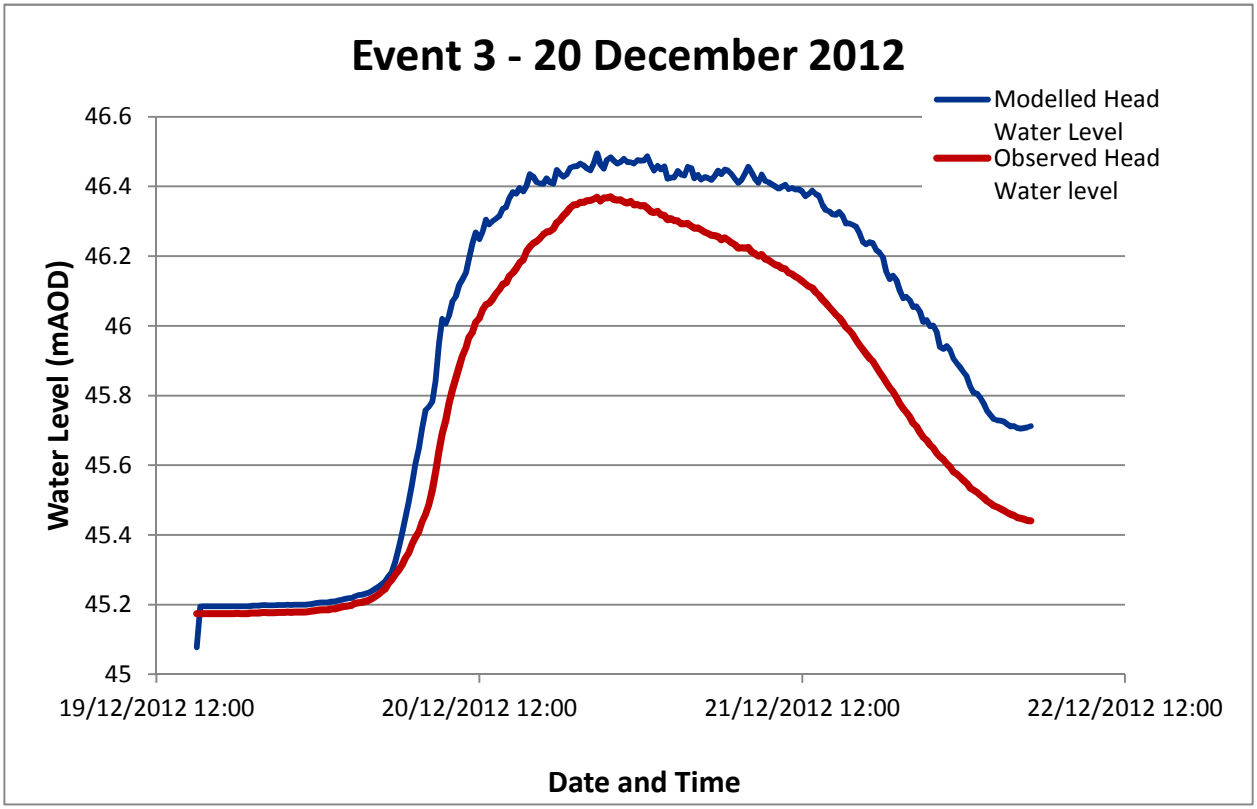
Event	Head water levels (mAOD)		Difference (m)
	Observed	Modelled	
18/01/2011	46.391	46.502	0.111
03/05/2012	46.517	46.474	-0.043
20/12/2012	46.37	46.495	0.125
07/02/2014	46.426	46.427	0.001

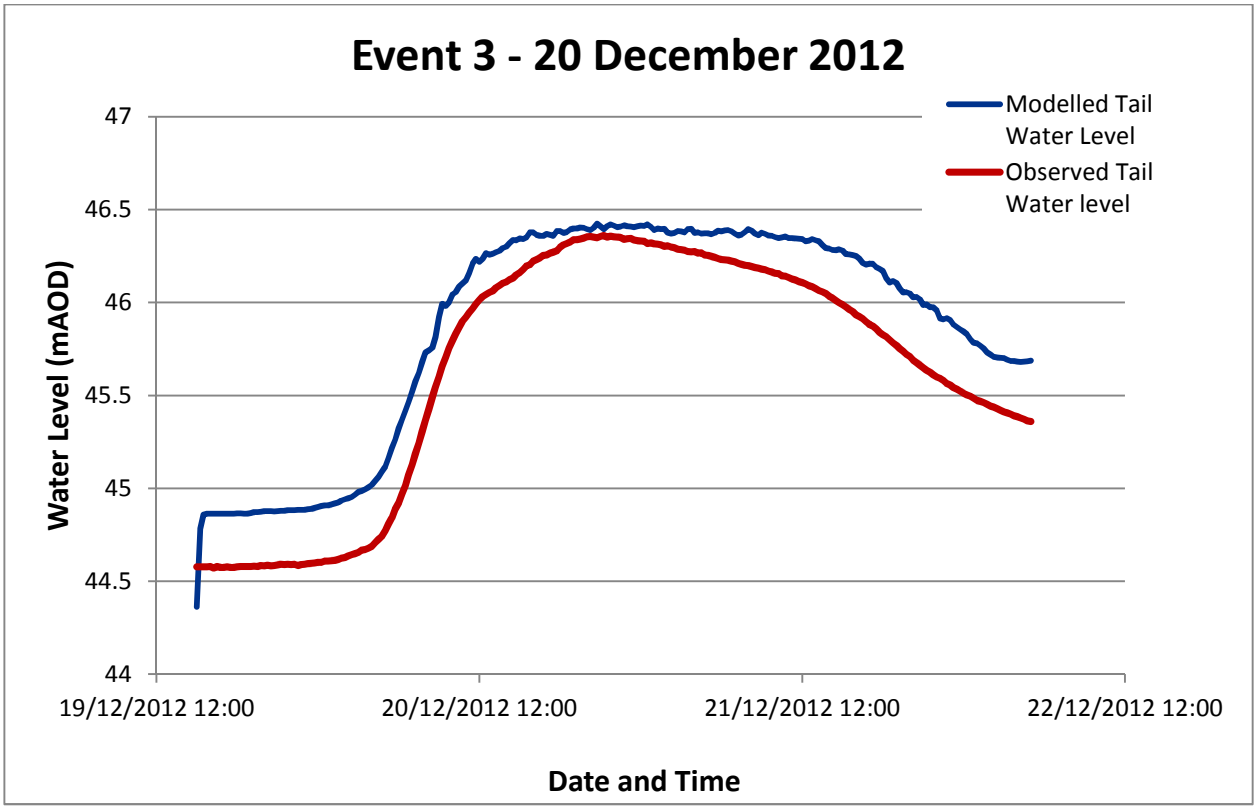


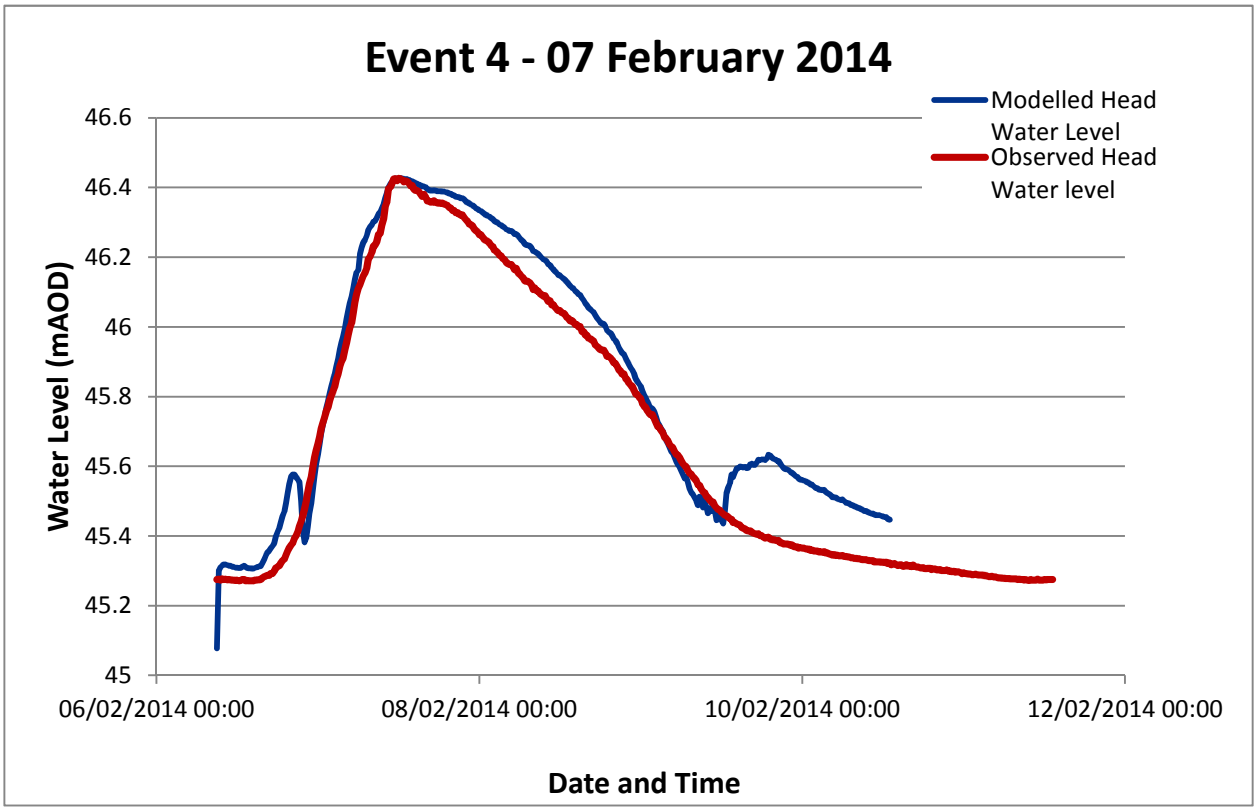

Event 1 - 18 January 2012
Modelled Tail Water Level
Observed Tail Water level
Water Level (mAOD)
47
46.5
46
45.5
45
44.5
44
16/01/2011 00:00
18/01/2011 00:00
20/01/2011 00:00
22/01/2011 00:00
Date and Time

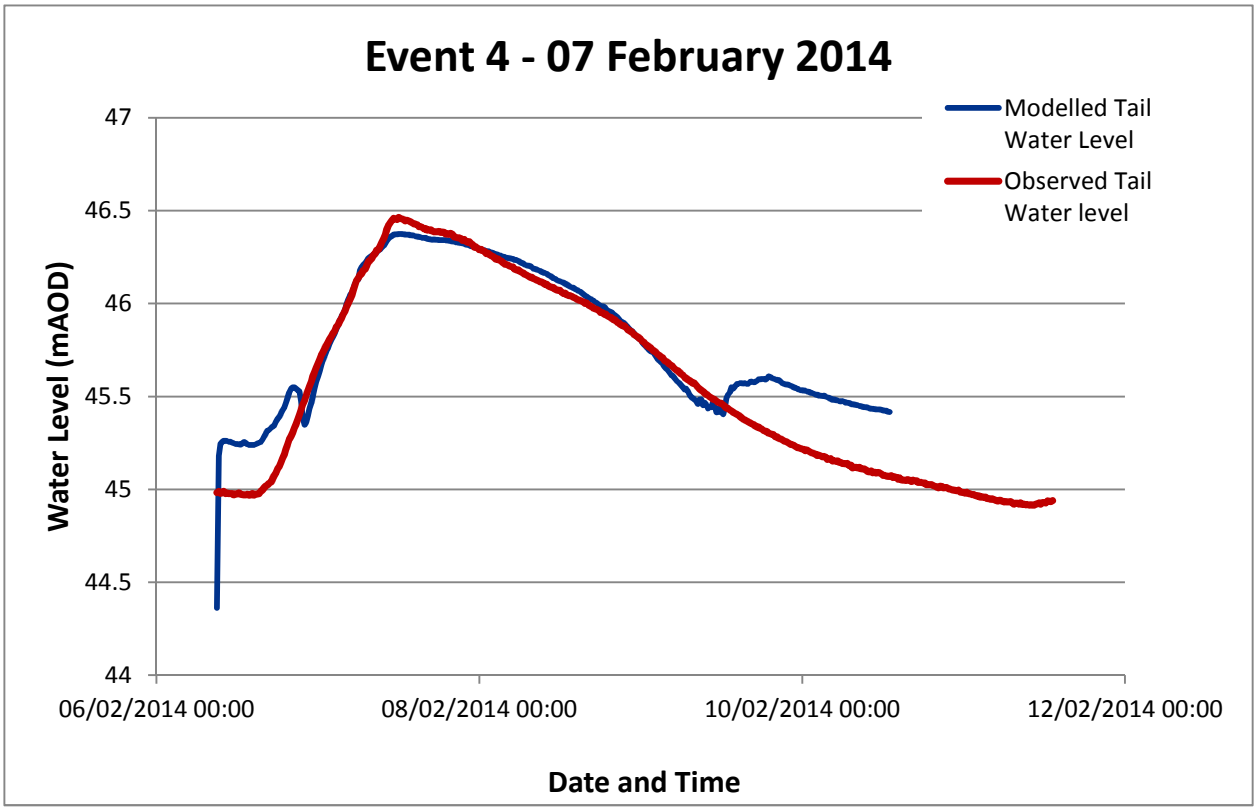

Event 2 - 03 May 2012
Modelled Head Water Level
Observed Head Water level
Water Level (mAOD)
46.6
46.4
46.2
46
45.8
45.6
45.4
45.2
45
27/04/2012 00:00
01/05/2012 00:00
05/05/2012 00:00
09/05/2012 00:00
Date and Time


Event 2 - 03 May 2012
Modelled Tail Water Level
Observed Tail Water level
Water Level (mAOD)
47
46.5
46
45.5
45
44.5
44
27/04/2012 00:00
01/05/2012 00:00
05/05/2012 00:00
09/05/2012 00:00
Date and Time


Event 3 - 20 December 2012
Modelled Head Water Level
Observed Head Water level
Water Level (mAOD)
46.6
46.4
46.2
46
45.8
45.6
45.4
45.2
45
19/12/2012 12:00
20/12/2012 12:00
21/12/2012 12:00
22/12/2012 12:00
Date and Time


Event 3 - 20 December 2012
Modelled Tail Water Level
Observed Tail Water level
Water Level (mAOD)
47
46.5
46
45.5
45
44.5
44
19/12/2012 12:00
20/12/2012 12:00
21/12/2012 12:00
22/12/2012 12:00
Date and Time


Event 4 - 07 February 2014
Modelled Head Water Level
Observed Head Water level
Water Level (mAOD)
46.6
46.4
46.2
46
45.8
45.6
45.4
45.2
45
06/02/2014 00:00
08/02/2014 00:00
10/02/2014 00:00
12/02/2014 00:00
Date and Time


Event 4 - 07 February 2014
Modelled Tail Water Level
Observed Tail Water level
Water Level (mAOD)
47
46.5
46
45.5
45
44.5
44
06/02/2014 00:00
08/02/2014 00:00
10/02/2014 00:00
12/02/2014 00:00
Date and Time

Appendix C. Tabulated Water levels and Flood Maps

Table C.1 - Baseline peak water levels extracted from the 1D model

Model Node	Do Minimum - Maximum Water Level (m AD)						
	50% AEP	20% AEP	5% AEP	1% AEP	1% AEP +35%CC	1% AEP +70%CC	0.1% AEP
PIN01_3535	48.638	48.881	49.070	49.224	49.311	49.365	49.457
PIN01_3473	48.558	48.800	48.966	49.102	49.218	49.300	49.413
PIN01_3377	48.480	48.706	48.818	48.911	49.025	49.121	49.279
PIN01_3282	48.307	48.532	48.646	48.768	48.892	48.991	49.169
PIN01_3202	48.118	48.348	48.501	48.621	48.740	48.836	49.042
PIN01_3123	47.896	48.149	48.381	48.517	48.628	48.717	48.946
PIN01_3044	47.698	47.950	48.202	48.346	48.466	48.587	48.904
PIN01_2965	47.569	47.806	48.094	48.284	48.362	48.470	48.843
PIN01_2868	47.387	47.590	47.870	48.106	48.290	48.447	48.838
PIN01_2868d	47.385	47.561	47.731	47.918	48.156	48.354	48.801
PIN01_2861	47.375	47.545	47.708	47.897	48.148	48.353	48.802
PIN01_2818	47.362	47.531	47.692	47.882	48.123	48.324	48.789
PIN01_2784	47.314	47.477	47.631	47.808	48.033	48.225	48.694
PIN01_2784c1	47.307	47.465	47.612	47.778	47.989	48.168	48.599
PIN01_2681c1	47.261	47.399	47.515	47.639	47.790	47.915	48.137
PIN01_2784c2	47.307	47.465	47.612	47.778	47.989	48.168	48.599
PIN01_2681c2	47.261	47.399	47.515	47.639	47.791	47.915	48.137
PIN01_2681	47.246	47.373	47.473	47.571	47.681	47.763	47.895
PIN01_2640	47.238	47.360	47.452	47.541	47.643	47.719	47.835
PIN01_2581	47.227	47.343	47.424	47.505	47.614	47.712	47.878
PIN01_2521	47.217	47.327	47.400	47.466	47.547	47.617	47.746
PIN01_2470	47.213	47.322	47.397	47.468	47.560	47.647	47.813
PIN01_2470d	47.209	47.317	47.389	47.456	47.538	47.611	47.756
PIN01_2467	47.209	47.317	47.389	47.456	47.539	47.612	47.757
PIN01_2444	47.204	47.308	47.373	47.428	47.491	47.551	47.696
PIN01_2388	47.195	47.296	47.357	47.405	47.446	47.482	47.619
PIN01_2316	47.184	47.280	47.340	47.391	47.440	47.491	47.558
PIN01_2272	47.169	47.266	47.328	47.389	47.458	47.482	47.630
PIN01_2266	46.697	46.897	47.022	47.134	47.248	47.339	47.478
PIN01_2246	46.649	46.851	46.979	47.101	47.224	47.311	47.460
PIN01_2192	46.603	46.790	46.896	47.012	47.129	47.218	47.382
PIN01_2164	46.583	46.764	46.854	46.950	47.051	47.137	47.315
PIN01_2143	46.566	46.748	46.845	46.941	47.037	47.119	47.296
PIN01_2100	46.509	46.681	46.768	46.861	46.958	47.052	47.255
PIN01_2030	46.441	46.601	46.700	46.803	46.910	47.016	47.240
PIN01_1980	46.419	46.574	46.683	46.779	46.873	46.968	47.190
PIN01_1967u	46.415	46.567	46.676	46.771	46.869	46.977	47.211
PIN01_1967d	46.365	46.497	46.627	46.705	46.785	46.904	47.167
PIN01_1957u	46.363	46.494	46.624	46.702	46.784	46.904	47.168
PIN01_1957d	46.363	46.494	46.624	46.702	46.784	46.904	47.168
PIN01_1952	46.371	46.512	46.607	46.684	46.768	46.904	47.173
PIN01_1925	46.326	46.461	46.543	46.610	46.689	46.857	47.150

PIN01_1872	45.988	46.158	46.280	46.363	46.508	46.778	47.115
PIN01_1809	45.599	45.822	46.011	46.166	46.426	46.753	47.102
PIN01_1745	45.471	45.712	45.900	46.094	46.403	46.745	47.098
PIN01_1680	45.427	45.667	45.857	46.065	46.390	46.739	47.094
PIN01_1627	45.410	45.645	45.830	46.043	46.377	46.731	47.087
PIN01_1533	45.333	45.573	45.772	46.000	46.353	46.717	47.077
PIN01_1520u	45.317	45.560	45.763	45.996	46.351	46.717	47.076
PIN01_1520d	45.317	45.560	45.763	45.996	46.351	46.717	47.076
PIN01_1482	45.277	45.516	45.734	45.979	46.343	46.712	47.072
PIN01_1404u	45.201	45.457	45.701	45.958	46.331	46.704	47.066
PIN01_1404d	45.201	45.457	45.701	45.958	46.331	46.704	47.066
PIN01_1330	45.153	45.427	45.684	45.950	46.331	46.706	47.068
PIN01_1278	45.121	45.384	45.623	45.870	46.237	46.611	46.986
PIN01_1278d	45.083	45.318	45.491	45.632	45.791	45.922	46.121
PIN01_1270	45.071	45.305	45.471	45.603	45.747	45.860	46.057
PIN01_1199	44.967	45.195	45.358	45.496	45.654	45.779	45.968
PIN01_1124	44.829	45.043	45.205	45.330	45.464	45.581	45.762
PIN01_1048	44.707	44.898	45.057	45.212	45.387	45.505	45.663
PIN01_0954	44.571	44.720	44.823	44.908	45.038	45.257	45.509
PIN01_0860	44.445	44.565	44.640	44.748	44.953	45.224	45.491
PIN01_0766	44.332	44.429	44.509	44.663	44.913	45.205	45.477
PIN01_0672	44.230	44.310	44.415	44.617	44.891	45.194	45.468
PIN01_0578	44.130	44.226	44.374	44.593	44.876	45.186	45.460
PIN01_0482	44.031	44.163	44.344	44.575	44.865	45.178	45.453
PIN01_0386	43.943	44.109	44.310	44.554	44.852	45.169	45.444
PIN01_0289	43.880	44.058	44.273	44.529	44.836	45.159	45.433
PIN01_0193	43.825	44.006	44.232	44.499	44.814	45.143	45.419
PIN01_0096	43.802	43.990	44.221	44.494	44.810	45.141	45.415
PIN01_0000	43.772	43.959	44.192	44.467	44.787	45.121	45.397
PIN01_0000c	43.751	43.924	44.140	44.393	44.687	44.994	45.246
PIN00_0200c	43.653	43.763	43.897	44.052	44.224	44.399	44.540
PIN01_0000r1	43.732	43.892	44.090	44.323	44.590	44.868	45.095
PIN00_0200r1	43.665	43.781	43.922	44.083	44.263	44.446	44.593
PIN01_0000r2	43.732	43.892	44.090	44.323	44.590	44.868	45.095
PIN00_0200r2	43.665	43.781	43.922	44.083	44.263	44.446	44.593
PIN00_0200	43.578	43.637	43.706	43.781	43.854	43.921	43.971
PIN00_0163	43.545	43.592	43.653	43.723	43.793	43.858	43.908
PIN00_0126	43.502	43.532	43.585	43.653	43.725	43.793	43.845
PIN00_0090	43.263	43.373	43.467	43.559	43.647	43.724	43.783
PIN00_0045	43.026	43.198	43.341	43.464	43.568	43.657	43.722
PIN00_0000	42.983	43.155	43.299	43.425	43.531	43.621	43.687
MOR01_0427	55.438	55.460	55.491	55.530	55.569	55.596	55.644
MOR01_0412	55.061	55.084	55.118	55.162	55.195	55.223	55.275
MOR01_0397	54.684	54.709	54.746	54.791	54.822	54.852	54.907
MOR01_0382	54.308	54.336	54.377	54.418	54.450	54.483	54.543
MOR01_0367	53.933	53.963	54.008	54.043	54.079	54.115	54.177
MOR01_0352	53.560	53.595	53.646	53.674	53.712	53.751	53.811
MOR01_0337	53.187	53.225	53.270	53.301	53.344	53.386	53.442
MOR01_0322	52.822	52.872	52.907	52.940	52.986	53.036	53.083

MOR01_0307	52.452	52.496	52.527	52.565	52.616	52.658	52.711
MOR01_0292	52.120	52.147	52.190	52.235	52.288	52.324	52.388
MOR01_0277	51.733	51.766	51.803	51.842	51.887	51.924	51.982
MOR01_0260	51.130	51.163	51.205	51.243	51.289	51.325	51.383
MOR01_0243	50.572	50.607	50.641	50.676	50.722	50.758	50.815
MOR01_0226	49.984	50.017	50.048	50.087	50.126	50.162	50.215
MOR01_0209	49.448	49.484	49.506	49.542	49.582	49.619	49.673
MOR01_0192	48.862	48.886	48.920	48.947	48.983	49.015	49.062
MOR01_0175	48.349	48.491	48.568	48.597	48.630	48.657	48.697
MOR01_0159	48.052	48.474	48.552	48.576	48.602	48.621	48.646
MOR01_0143	47.829	48.472	48.550	48.573	48.596	48.613	48.633
MOR01_0126	47.760	48.472	48.550	48.573	48.596	48.613	48.632
MOR01_0126c	47.537	48.388	48.468	48.495	48.523	48.544	48.571
MOR01_0101c	46.935	47.807	47.929	48.004	48.102	48.191	48.285
MOR01_0076c	46.558	47.233	47.424	47.547	47.706	47.856	48.011
MOR01_0050c	46.197	46.668	46.924	47.094	47.311	47.524	47.738
MOR01_0025c	45.837	46.124	46.427	46.643	46.917	47.193	47.467
MOR01_0000c	45.476	45.719	45.942	46.194	46.525	46.862	47.196

Table C.2 – With-scheme peak water levels extracted from the 1D model

Model Node	Do Minimum - Maximum Water Level (m AD)						
	50% AEP	20% AEP	5% AEP	1% AEP	1% AEP +35%CC	1% AEP +70%CC	0.1% AEP
PIN01_3535	48.638	48.881	49.070	49.224	49.311	49.365	49.457
PIN01_3473	48.558	48.800	48.966	49.102	49.218	49.300	49.413
PIN01_3377	48.480	48.706	48.819	48.911	49.025	49.121	49.279
PIN01_3282	48.307	48.532	48.647	48.768	48.892	48.991	49.169
PIN01_3202	48.118	48.348	48.501	48.621	48.740	48.836	49.042
PIN01_3123	47.896	48.149	48.381	48.517	48.628	48.717	48.946
PIN01_3044	47.698	47.950	48.202	48.346	48.466	48.588	48.905
PIN01_2965	47.569	47.806	48.094	48.284	48.362	48.471	48.843
PIN01_2868	47.387	47.590	47.870	48.106	48.290	48.447	48.838
PIN01_2868d	47.385	47.561	47.731	47.918	48.156	48.355	48.802
PIN01_2861	47.375	47.545	47.708	47.897	48.148	48.353	48.803
PIN01_2818	47.362	47.531	47.692	47.882	48.123	48.325	48.790
PIN01_2784	47.314	47.477	47.632	47.807	48.033	48.226	48.694
PIN01_2784c1	47.306	47.465	47.612	47.778	47.989	48.169	48.600
PIN01_2681c1	47.261	47.399	47.515	47.639	47.790	47.915	48.138
PIN01_2784c2	47.306	47.465	47.612	47.778	47.989	48.169	48.600
PIN01_2681c2	47.261	47.399	47.515	47.639	47.790	47.915	48.138
PIN01_2681	47.246	47.373	47.473	47.571	47.681	47.763	47.896
PIN01_2640	47.238	47.360	47.452	47.541	47.643	47.719	47.836
PIN01_2581	47.227	47.343	47.424	47.504	47.614	47.712	47.879
PIN01_2521	47.217	47.327	47.400	47.466	47.547	47.618	47.747
PIN01_2470	47.213	47.322	47.397	47.468	47.560	47.648	47.814
PIN01_2470d	47.209	47.317	47.389	47.456	47.538	47.611	47.758
PIN01_2467	47.209	47.317	47.389	47.456	47.539	47.612	47.759
PIN01_2444	47.204	47.308	47.373	47.428	47.491	47.551	47.698
PIN01_2388	47.195	47.296	47.357	47.405	47.446	47.486	47.622
PIN01_2316	47.184	47.280	47.340	47.391	47.440	47.494	47.560
PIN01_2272	47.169	47.266	47.328	47.388	47.458	47.484	47.633
PIN01_2266	46.697	46.897	47.023	47.134	47.248	47.339	47.482
PIN01_2246	46.649	46.851	46.980	47.101	47.224	47.312	47.466
PIN01_2192	46.603	46.790	46.897	47.012	47.129	47.219	47.389
PIN01_2164	46.583	46.764	46.855	46.950	47.051	47.138	47.325
PIN01_2143	46.566	46.748	46.845	46.941	47.037	47.119	47.306
PIN01_2100	46.509	46.681	46.769	46.861	46.958	47.053	47.267
PIN01_2030	46.441	46.601	46.701	46.803	46.910	47.017	47.253
PIN01_1980	46.419	46.574	46.684	46.779	46.873	46.970	47.206
PIN01_1967u	46.415	46.567	46.677	46.771	46.869	46.978	47.227
PIN01_1967d	46.365	46.497	46.628	46.705	46.785	46.906	47.186
PIN01_1957u	46.363	46.494	46.625	46.702	46.784	46.905	47.187
PIN01_1957d	46.363	46.494	46.625	46.702	46.784	46.905	47.187
PIN01_1952	46.371	46.512	46.607	46.684	46.768	46.906	47.192
PIN01_1925	46.326	46.462	46.544	46.610	46.689	46.859	47.170
PIN01_1872	45.987	46.158	46.280	46.363	46.509	46.781	47.137
PIN01_1809	45.596	45.821	46.012	46.166	46.427	46.756	47.125
PIN01_1745	45.468	45.710	45.901	46.094	46.404	46.748	47.121

PIN01_1680	45.423	45.665	45.857	46.064	46.391	46.742	47.117
PIN01_1627	45.406	45.643	45.830	46.042	46.378	46.734	47.111
PIN01_1533	45.328	45.570	45.771	45.999	46.354	46.721	47.101
PIN01_1520u	45.312	45.556	45.763	45.995	46.352	46.720	47.101
PIN01_1520d	45.312	45.556	45.763	45.995	46.352	46.720	47.101
PIN01_1482	45.274	45.512	45.734	45.977	46.344	46.715	47.097
PIN01_1404u	45.200	45.451	45.701	45.957	46.333	46.708	47.091
PIN01_1404d	45.200	45.451	45.701	45.957	46.333	46.708	47.091
PIN01_1330d	45.154	45.425	45.684	45.948	46.330	46.709	47.092
PIN01_1278	45.121	45.384	45.624	45.869	46.237	46.614	47.008
PIN01_1278d	45.083	45.318	45.492	45.631	45.791	45.922	46.121
PIN01_1270	45.071	45.305	45.472	45.602	45.747	45.861	46.055
PIN01_1199	44.967	45.196	45.359	45.495	45.654	45.780	45.968
PIN01_1124	44.828	45.043	45.206	45.329	45.464	45.582	45.762
PIN01_1048	44.706	44.898	45.058	45.211	45.387	45.505	45.663
PIN01_0954	44.569	44.720	44.824	44.907	45.038	45.258	45.508
PIN01_0860	44.444	44.565	44.641	44.747	44.953	45.225	45.490
PIN01_0766	44.331	44.429	44.509	44.662	44.913	45.206	45.476
PIN01_0672	44.229	44.310	44.415	44.616	44.891	45.195	45.467
PIN01_0578	44.130	44.226	44.373	44.592	44.876	45.187	45.459
PIN01_0482	44.031	44.163	44.344	44.574	44.865	45.179	45.452
PIN01_0386	43.942	44.109	44.309	44.553	44.851	45.170	45.443
PIN01_0289	43.880	44.058	44.273	44.529	44.835	45.160	45.432
PIN01_0193	43.824	44.006	44.231	44.499	44.813	45.144	45.418
PIN01_0096	43.802	43.990	44.220	44.494	44.810	45.142	45.414
PIN01_0000	43.771	43.959	44.190	44.467	44.787	45.122	45.396
PIN01_0000c	43.750	43.924	44.138	44.393	44.687	44.994	45.245
PIN00_0200c	43.652	43.763	43.896	44.052	44.224	44.400	44.540
PIN01_0000r1	43.731	43.892	44.089	44.323	44.590	44.868	45.094
PIN00_0200r1	43.664	43.781	43.921	44.083	44.263	44.447	44.593
PIN01_0000r2	43.731	43.892	44.089	44.323	44.590	44.868	45.094
PIN00_0200r2	43.664	43.781	43.921	44.083	44.263	44.447	44.593
PIN00_0200	43.578	43.637	43.706	43.781	43.854	43.922	43.970
PIN00_0163	43.545	43.592	43.653	43.723	43.793	43.859	43.907
PIN00_0126	43.502	43.532	43.585	43.653	43.725	43.793	43.844
PIN00_0090	43.262	43.373	43.467	43.559	43.647	43.724	43.783
PIN00_0045	43.025	43.198	43.340	43.464	43.568	43.657	43.721
PIN00_0000	42.982	43.155	43.299	43.425	43.531	43.621	43.687
MOR01_0545	55.443	55.467	55.501	55.543	55.577	55.606	55.659
MOR01_0535	55.233	55.257	55.291	55.334	55.368	55.398	55.452
MOR01_0525	55.022	55.046	55.081	55.125	55.159	55.190	55.245
MOR01_0516	54.812	54.836	54.871	54.916	54.951	54.982	55.038
MOR01_0506	54.600	54.625	54.662	54.707	54.742	54.774	54.832
MOR01_0496	54.391	54.416	54.452	54.498	54.533	54.566	54.626
MOR01_0486	54.177	54.204	54.242	54.289	54.324	54.359	54.420
MOR01_0476	53.971	53.997	54.034	54.082	54.117	54.152	54.214
MOR01_0467	53.753	53.780	53.820	53.867	53.905	53.942	54.008
MOR01_0457	53.558	53.590	53.630	53.672	53.713	53.753	53.816
MOR01_0447	53.330	53.360	53.393	53.429	53.471	53.507	53.563

MOR01_0439	53.093	53.123	53.156	53.192	53.233	53.270	53.325
MOR01_0431	52.855	52.885	52.918	52.954	52.996	53.032	53.088
MOR01_0423	52.618	52.649	52.681	52.717	52.758	52.795	52.850
MOR01_0421	52.560	52.594	52.624	52.659	52.699	52.735	52.789
MOR01_0419	52.511	52.551	52.573	52.603	52.640	52.673	52.727
MOR01_0417	52.478	52.527	52.545	52.554	52.583	52.605	52.648
MOR01_0415u	52.319	52.339	52.366	52.396	52.433	52.466	52.521
MOR01_0415i	52.319	52.339	52.366	52.396	52.433	52.466	52.521
MOR01_0415c	52.316	52.334	52.359	52.386	52.419	52.449	52.497
MOR01_0406	52.052	52.070	52.095	52.123	52.156	52.185	52.233
MOR01_0397	51.790	51.808	51.832	51.859	51.892	51.922	51.970
MOR01_0388	51.523	51.542	51.568	51.595	51.628	51.658	51.706
MOR01_0380	51.264	51.282	51.306	51.333	51.365	51.394	51.443
MOR01_0371	50.994	51.014	51.039	51.068	51.101	51.132	51.180
MOR01_0362	50.740	50.758	50.781	50.807	50.838	50.866	50.913
MOR01_0353	50.463	50.483	50.509	50.538	50.574	50.608	50.658
MOR01_0344c	50.274	50.306	50.341	50.380	50.426	50.466	50.528
MOR01_0344o	50.271	50.301	50.334	50.370	50.412	50.448	50.504
MOR01_0344d	50.271	50.301	50.334	50.370	50.412	50.448	50.504
MOR01_0335	50.000	50.030	50.063	50.099	50.141	50.177	50.233
MOR01_0326	49.729	49.759	49.792	49.828	49.870	49.906	49.962
MOR01_0317	49.458	49.488	49.521	49.557	49.599	49.635	49.690
MOR01_0308	49.187	49.217	49.250	49.286	49.328	49.364	49.419
MOR01_0298	48.916	48.946	48.979	49.015	49.057	49.093	49.148
MOR01_0289	48.645	48.675	48.708	48.744	48.786	48.822	48.877
MOR01_0287	48.577	48.607	48.640	48.676	48.718	48.754	48.810
MOR01_0285	48.510	48.540	48.573	48.608	48.650	48.687	48.742
MOR01_0283	48.442	48.472	48.505	48.541	48.583	48.619	48.674
MOR01_0280	48.374	48.405	48.437	48.473	48.515	48.551	48.606
MOR01_0278	48.308	48.342	48.371	48.407	48.447	48.483	48.538
MOR01_0276	48.254	48.296	48.314	48.344	48.381	48.414	48.468
MOR01_0274	48.222	48.272	48.290	48.292	48.320	48.342	48.385
MOR01_0271u	48.042	48.063	48.090	48.121	48.158	48.192	48.246
MOR01_0271i	48.042	48.063	48.090	48.121	48.158	48.192	48.246
MOR01_0271c	48.039	48.058	48.084	48.112	48.145	48.174	48.222
MOR01_0264	47.823	47.840	47.863	47.888	47.920	47.950	47.999
MOR01_0256	47.602	47.624	47.652	47.686	47.729	47.767	47.825
MOR01_0249c	47.480	47.511	47.549	47.593	47.647	47.693	47.762
MOR01_0249o	47.477	47.508	47.543	47.586	47.636	47.679	47.743
MOR01_0249d	47.477	47.508	47.543	47.586	47.636	47.679	47.743
MOR01_0202	46.816	46.845	46.894	46.939	46.988	47.030	47.136
MOR01_0162	46.376	46.404	46.441	46.486	46.551	46.729	47.100
MOR01_0121	45.943	45.970	46.031	46.090	46.347	46.717	47.098
MOR01_0081	45.503	45.529	45.706	45.959	46.335	46.710	47.092
MOR01_0040	45.182	45.420	45.692	45.951	46.331	46.708	47.091
MOR01_0000	45.154	45.437	45.686	45.948	46.330	46.707	47.089
MOR01_0000d	45.154	45.425	45.684	45.948	46.330	46.709	47.092