

Appendix 3: Hydraulic Modelling Report

ENVIRONMENT

Richborough Estates Limited and Mr & Mrs Adcock
Land East of Stoke Road and North of
Normandy Way (A47)
Hinckley
Hydraulic Model Report

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Birmingham
Livery Place, 35 Livery Street, Colmore Business District, Birmingham, B3 2PB
T: 0121 233 3322

Cambridge
14-16 High Street, Histon, Cambridge
CB24 9JD
T: 01223 235 173

Leeds
Whitehall Waterfront, 2 Riverside Way, Leeds
LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street, Manchester, M1 3HU
0161 233 4260

Market Harborough
12a Woodcock House, Compass Point Market Harborough, Leicestershire, LE16 9HW
T: 01858 455020

Nottingham
Waterfront House, Station Street, Nottingham NG2 3DQ
T: 0115 924 1100

March 2022

DOCUMENT ISSUE RECORD

Document Number:	HIN-BWB-ZZ-XX-RP-YE-0002_HMR
BWB Reference:	210683_HMR

Rev	Date	Status	Comment	Author:	Checked:	Approved:
P01	31/03/22	S2	Draft Issue	Lucy Reeves BSc (Hons)	Max Brambani BSc (Hons) PgCert MCIWEM	Matthew Day BA (Hons) MSc FRGS MCIWEM C.WEM C.Sci C.Env

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GLOSSARY & NOTATION

1D – one-dimensional hydraulic model, good for representing the hydraulics of a definitive channel or flow pathway and hydraulic structure.

2D – two-dimensional hydraulic model, good for representing complex flow routing present within the floodplain.

Annual Exceedance Probability (AEP) - the probability (%) of a flood event occurring in any year.

Catchment - the land area that drains (normally naturally) to a given point on a river, drainage system or body of water.

Design flood event - magnitude of the flood adopted for the design of the whole or part of a development, usually defined in relation to the severity of the flood in terms of its return period. Typically, the 1 in 100-year return period event including an allowance for future climate change for fluvial flood events.

DTM – Digital Terrain Model

EA – Environment Agency

ESTRY - a 1D hydraulic modelling software package published by BMT.

Flood Estimation Handbook (FEH) – industry standard guidance on rainfall and river flood frequency estimation across the UK.

Floodplain - any area of land over which water flows or is stored during a flood event.

FRA – Flood Risk Assessment

Freeboard - the height of the top of a bank, floodwall or other flood defence structure, above the design water level. Freeboard can be seen as a safety margin that makes allowance for uncertainty associated with the potentially damaging effects of flood rise or wave action.

Hydraulic Model - a mathematical (generally computer based) model of a water/sewer/storm system which is used to analyse the system's hydraulic behaviour.

LiDAR – Light Detection and Ranging aerial survey data

LLFA – Lead Local Flood Authority

mAOD – metres above Ordnance Datum

m BGL – metres below ground level

Main River - a statutory type of watercourse in England and Wales, usually larger streams and rivers. The EA can carry out maintenance, improvement or construction work on main rivers to manage flood risk as part of its duties and powers.

NRFA – National River Flow Archive

OS – Ordnance Survey

Preliminary Flood Risk Assessment (PFRA) - an assessment of floods that have taken place in the past and floods that could take place in the future. It generally considers flooding from surface water runoff, groundwater and ordinary watercourses, and is prepared by the Lead Local Flood Authority.

ReFH – Revitalised Flood Hydrograph rainfall-runoff hydrological model

Return period - a statistical term defining the probability of occurrence of a flood event. Thus a 1 in 50-year flood is one likely to be equalled or exceeded on average only once in a 50-year period: a flood with a 2.0% annual probability exceedance (AEP).

Strategic Flood Risk Assessment (SFRA) - a study carried out by one or more local planning authorities to assess the risk to an area from flooding from all sources, now and in the future.

TUFLOW – a 2D fixed grid hydraulic modelling software package published by BMT.

UOW – Unnamed Ordinary Watercourse

Watercourse – a natural or man-made open channel for the conveyance of water.

Z-line – a break line layer in TUFLOW which can be used to reinforce linear features in the 2D model domain such as a riverbank, flood defence, or channel bed.

Z-Shape – a layer in TUFLOW which can be used to manipulate the 2D model geometry.

1. INTRODUCTION

- 1.1 BWB Consulting Ltd has been commissioned by Richborough Estates Limited and Mr & Mrs Adcock to undertake a site-specific hydraulic modelling exercise of an Unnamed Ordinary Watercourse (UOW) and a series of ditches to support a proposed residential development at the Land East of Stoke Road and North of Normandy Way, Hinckley (NGR: SP419956).

Aims and Objectives.

- 1.2 This modelling exercise will be used to establish a good hydrological and hydraulic representation of the flooding mechanisms to the site and within the wider vicinity. Modelled floodplain extents and flood levels will be used to support a Flood Risk Assessment (FRA). The following objectives have been identified:
- i. Undertake a hydrological review of the Unnamed Ordinary Watercourse and ditches within the vicinity of the site to estimate peak flows and general flood hydrograph profiles.
 - ii. Construct a one-dimensional (1D) representation of the in-channel environment, where topographical survey is available, including structures using ESTRY software.
 - iii. Construct a two-dimensional (2D) representation of the floodplain using TUFLOW software.
 - iv. Combine and link the 1D and 2D model domains.
 - v. Undertake simulations of key flood return period events to understand the floodplain extents and peak flood levels within and adjacent to the site.
 - vi. Undertake simulations to account for climate change flows within the model.
 - vii. Undertake sensitivity analysis of baseline conditions.

Approach

- 1.3 In order to achieve the objectives identified above, a new 1D/2D ESTRY-TUFLOW model was constructed, based on a watercourse survey completed by BWB Consulting Ltd in February 2022 (Reference: HIN-BWB-ZZ-M2-G-0060, see **Appendix 1**).
- 1.4 The model has been simulated for a series of design storm events. These modelled events include the 1 in 20-year, 1 in 100-year and 1 in 1000-year events that are typically used by the Environment Agency (EA) for planning purposes to define Flood Zones 3b, 3a and 2 respectively.
- 1.5 Simulations have been run to account for the impacts of climate change in accordance with the allowances released by the EA in July 2021. This is necessary so that the FRA can assess the risk of flooding to the proposed development over the length of the anticipated lifetime.
- 1.6 Sensitivity testing has also been undertaken to understand what impacts changes to roughness and downstream boundary has upon the model outputs and to increase confidence in the outputs of the hydraulic modelling.

- 1.7 The modelled flood extents and peak water levels from this study have been assessed in the associated FRA (reference: HIN-BWB-ZZ-XX-RP-YE-0003). Following an assessment of the development proposals, appropriate development levels and mitigation measures have been recommended as part of the FRA.

Site Description

- 1.8 The site is located approximately 1.7km north of Hinckley town centre. The site is bound to the north by agricultural land, to the east by an Unnamed Ordinary Watercourse (UOW) to the south by Normandy Way (A47) and to the west by a pond and further greenfield land. Stoke Road is shown to pass through the site boundary.
- 1.9 The site location is shown in **Figure 1.1**.

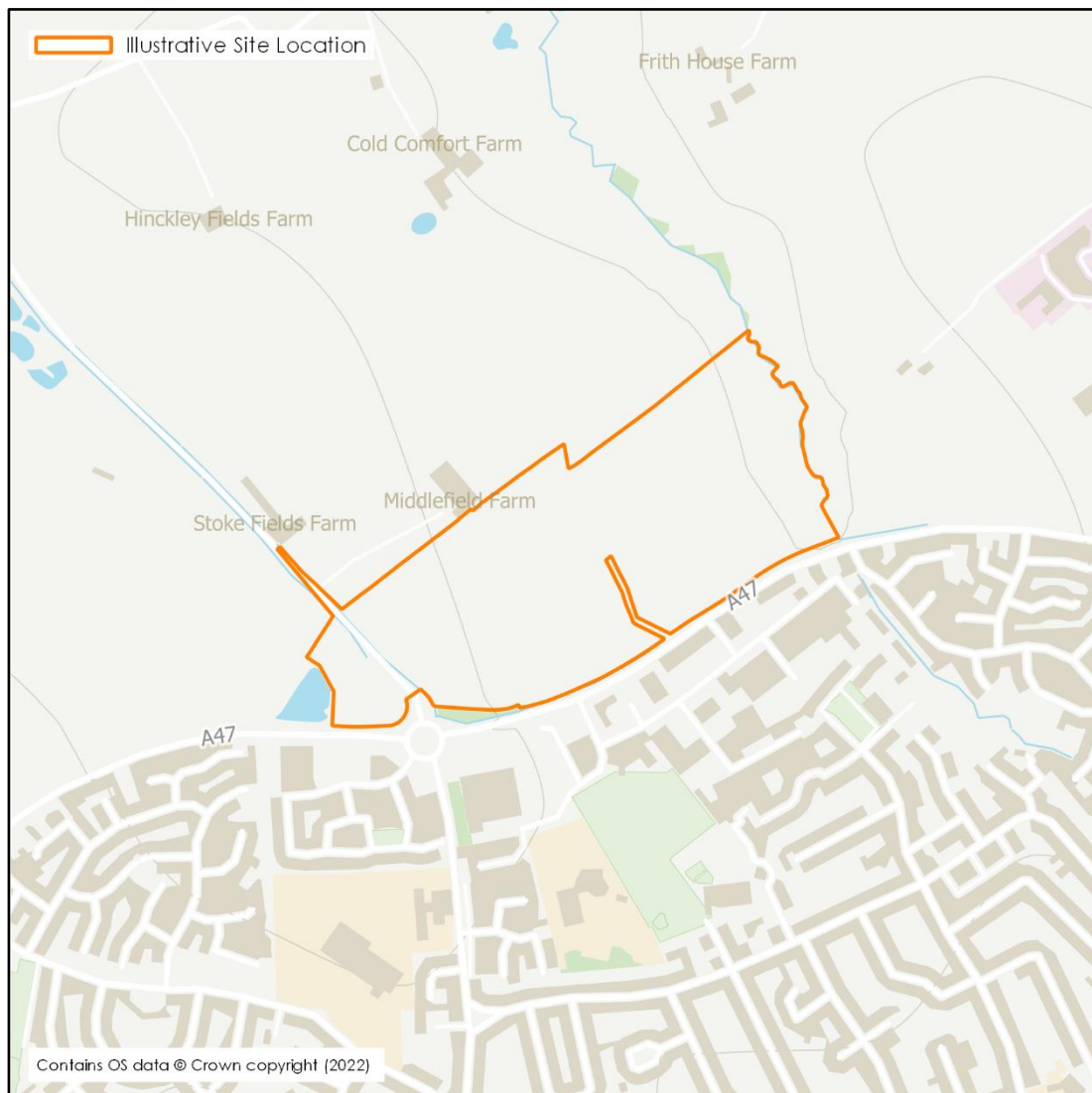


Figure 1.1: Site location

- 1.10 A topographical survey has been undertaken to inform the study. The land parcel to the west of Stoke Road is shown to generally fall in a northerly direction. Site levels are shown

to range from approximately 106.1metres Above Ordnance Datum (mAOD) in the south to approximately 104.5mAOD in the north.

- 1.11 Ground levels across the main land parcel rise away from Stoke Road to the west and the UOW to the east. The centre of the site subsequently forms a topographical high point, defining a split between two catchments. Site levels within the eastern catchment are shown to range from approximately 119.0mAOD at the centre of the site to approximately 106.5mAOD in the north east. Site levels within the western catchment are shown to range from approximately 119.0mAOD to 104.8mAOD in the north west. The site contours are displayed in **Figure 1.2**.

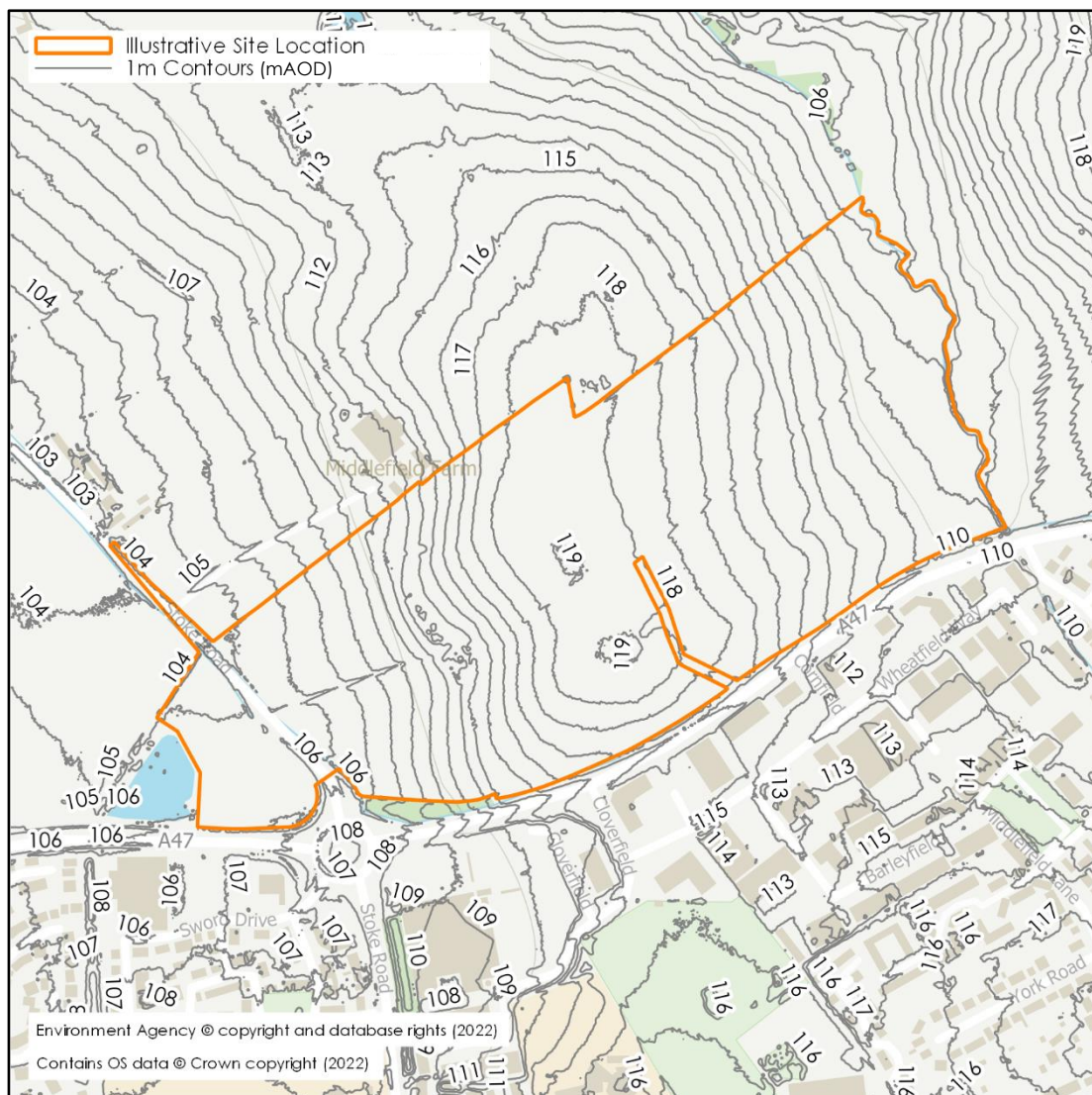


Figure 1.2: Site Topography

Local Watercourses

- 1.12 An Unnamed Ordinary Watercourse (UOW) flows along the eastern boundary of the site in a northerly direction. The watercourse is a tributary of the River Tweed. The UOW flows from within the urban development to the south of the site via twin 0.5m diameter circular culverts beneath Normandy Way. The UOW then flows adjacent to the

perimeter of the site as an open channel. Severn Trent Water sewer records demonstrate that two surface water sewers, that drain residential areas in the upper limits of the catchment, outfall to the river immediately downstream of Normandy Way.

- 1.13 A series of ditches/highway drains are shown to be located within the vicinity of Stoke Road at the western portion of the site boundary. Two of the ditches (R2 & R3) are shown to flow adjacent to either side of Stoke Road in a north westerly direction. A further ditch (R4) is shown to flow towards Stoke Road from Normandy Way and is assumed to outfall to the ditch (R2) immediately east of Stoke Road.
- 1.14 The ditches are understood to be fed by surface water sewers originating within the urban development to the south of Normandy Way and are therefore considered to be more representative of surface water flooding mechanisms.
- 1.15 **Figure 1.3** shows the local watercourse network. The watercourse labels shown will be referenced throughout this report with R2, R3 and R4, as a collective, referred to as the 'western ditches'.

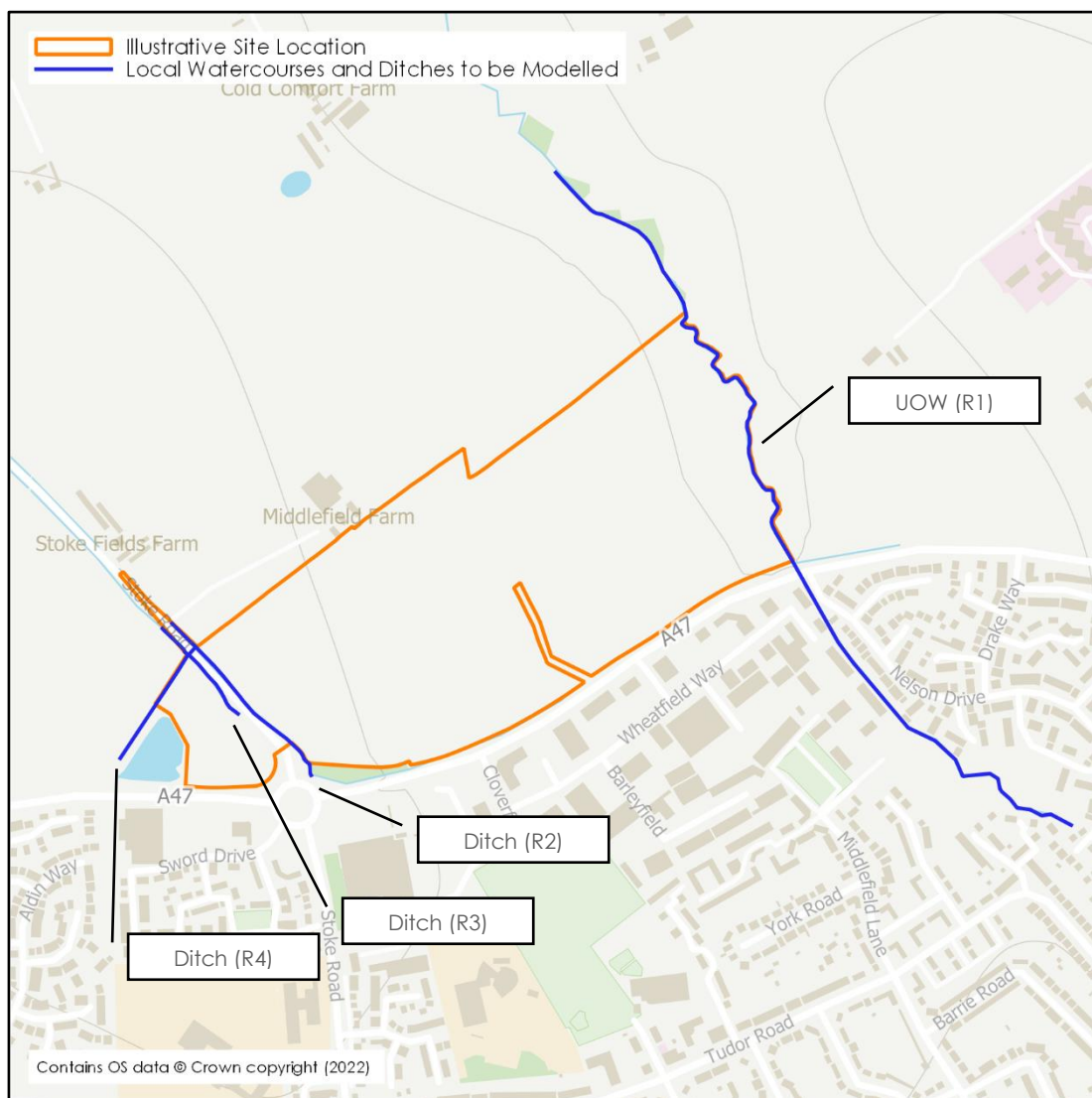


Figure 1.3: Watercourse Network

- 1.16 The UOW (R1) has a total catchment area of approximately 2.1km², R2 and R3 have a catchment area of 0.7km² and R4 has a catchment area of 0.3km². The watercourses and ditches are fed by surface water sewers, which outfall to the waterbodies downstream of Normandy Way. The modelled catchments are displayed in **Figure 1.4**.

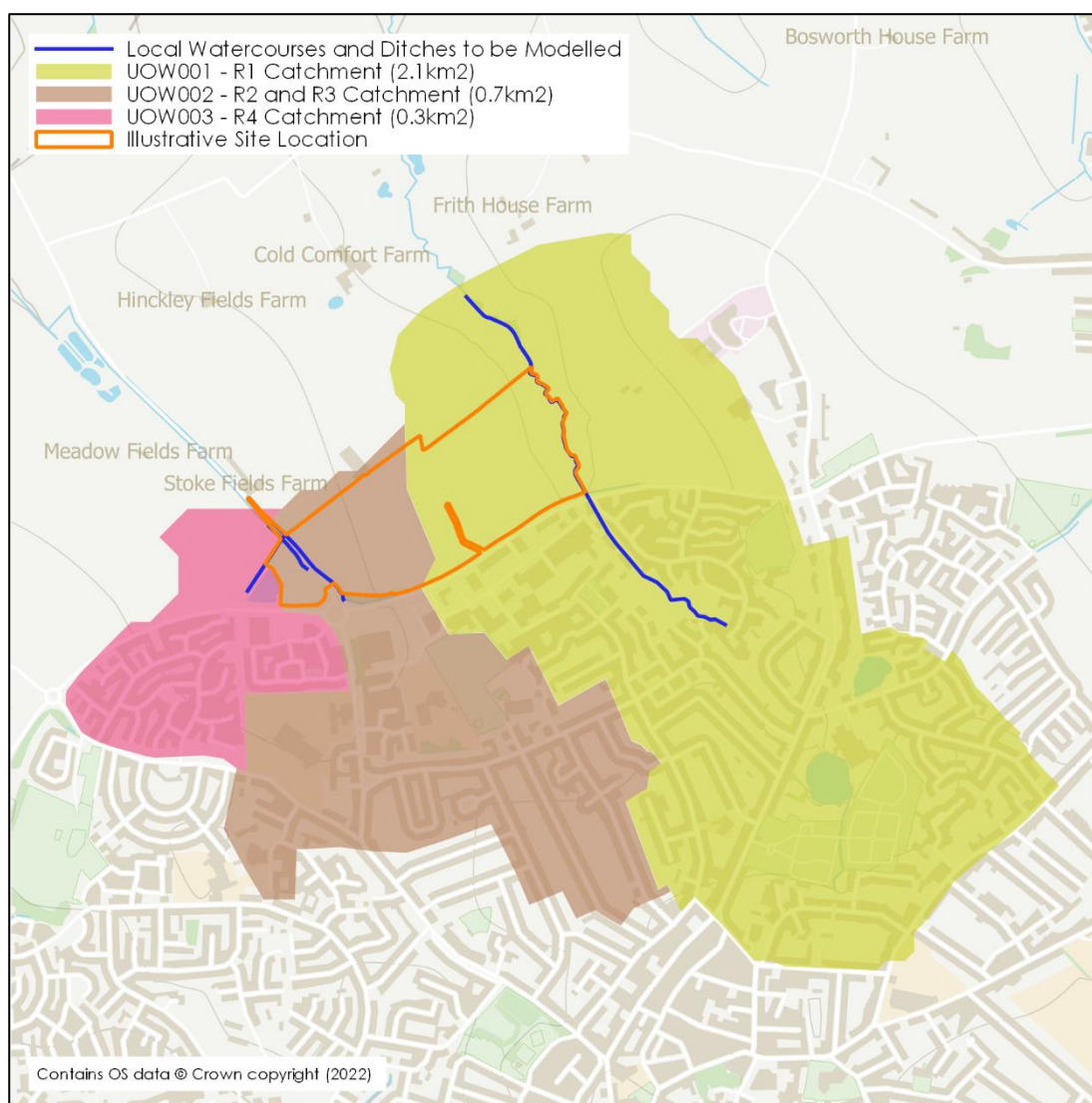


Figure 1.4: Modelled Catchment Areas

Previous Studies & Available Data

Historic Flood Events

- 1.17 A flood history review for the catchment has been undertaken using EA recorded flood outlines, Hinckley and Bosworth Borough Council Level 1 Strategic Flood Risk Assessment (SFRA)¹, Hinckley and Bosworth Borough Council Level 2 SFRA², Leicestershire County Council Preliminary Flood Risk Assessment (PFRA)³, Leicestershire

¹ Level 1 Strategic Flood Risk Assessment (JBA Consulting, July 2019)

² Level 2 Strategic Flood Risk Assessment (JBA Consulting, May 2020)

³ Preliminary Flood Risk Assessment (Leicestershire County Council, June 2011)

County Council Local Flood Risk Management Strategy (LFRMS)⁴, the British Chronology of Hydrological Events and online newspaper records.

- 1.18 The Level 1 SFRA notes that a surface water overland flow route exists along Stoke Road and is associated with an unnamed drain adjacent to this road, however there are no historic flooding incidents recorded. It is unknown whether this surface water flow route affects the development site.
- 1.19 The Environment Agency (EA) recorded flood outline information does not include any historical records within proximity of the site. Given the greenfield nature of the site and lack of receptors, this does not necessarily mean that the site has never flooded.
- 1.20 Following consultation with Severn Trent Water, it was confirmed that no information is held on ditches R2, R3 and R4. It was stated, however, that whilst no locations of flooding have been identified, they are aware of capacity issues regarding the surface water sewer network within this area.

BWB Site Visit (January 2022)

- 1.21 A site visit was undertaken by BWB during January 2022 to walk the local watercourse reaches and observe any key features that either needed surveying or needed to be considered during the hydraulic modelling process. The key considerations have been summarised below:
- The UOW (R1) to the east of the site flows in a northerly direction. A brick arch structure was observed looking upstream towards the culvert beneath Normandy Way. Adjacent to the site, the watercourse follows the site boundary as open channel with some small structures along this reach.
 - The ditch located immediately east of Stoke Road (R2) is shown to be culverted at the head of the reach. It was not possible to trace back to an open reach of the watercourse within the town of Hinckley, with manholes notable at the Morrisons car park on the southern side of Normandy Way.
 - A detention basin is located adjacent to R4. No outfall from the detention basin could be identified due to access restrictions within this part of the site. It is assumed that the basin likely discharges into R4, the adjacent ditch.
 - The upstream limit of R3 appeared dry at the time of the site visit.

Environment Agency Flood Maps

- 1.22 The EA Flood Map for Planning confirms the site as being located entirely within Flood Zone 1. This is likely to be due to the smaller catchments associated with the UOW and ditches which means they have been excluded from the national scale mapping. Subsequently, no existing detailed model information is held by the EA at the site.
- 1.23 The closest Flood Zones to the site are located approximately 1.3km downstream. The Flood Map is displayed in **Figure 1.5**.

⁴Local Flood Risk Management Strategy (Leicestershire County Council, August 2015)



Figure 1.5: EA Flood Map

Environment Agency Surface Water Maps

- 1.24 The EA Risk of Flooding from Surface Water mapping provides an indication of the floodplain associated with ordinary watercourses that are not included in the Flood Map for Planning. The surface water mapping is included within **Figure 1.6**.
- 1.25 The mapping shows that pluvial flow routes overtop Normandy Way (A47) both upstream of the UOW (R1) and the western ditches. The surface water extent along R2 is relatively contained to the capacity of the channel with some out of bank flooding predicted at lower ground levels immediately adjacent to the site and downstream of the site. Isolated areas of surface water flooding are seen in the site which are attributed to existing hedgerows (with drainage ditches) and a pond/topographical depression in the centre of the site. The field between the existing detention basin and Stoke Road is predicted to convey overtopping surface water from Normandy Way into R3 and R4.

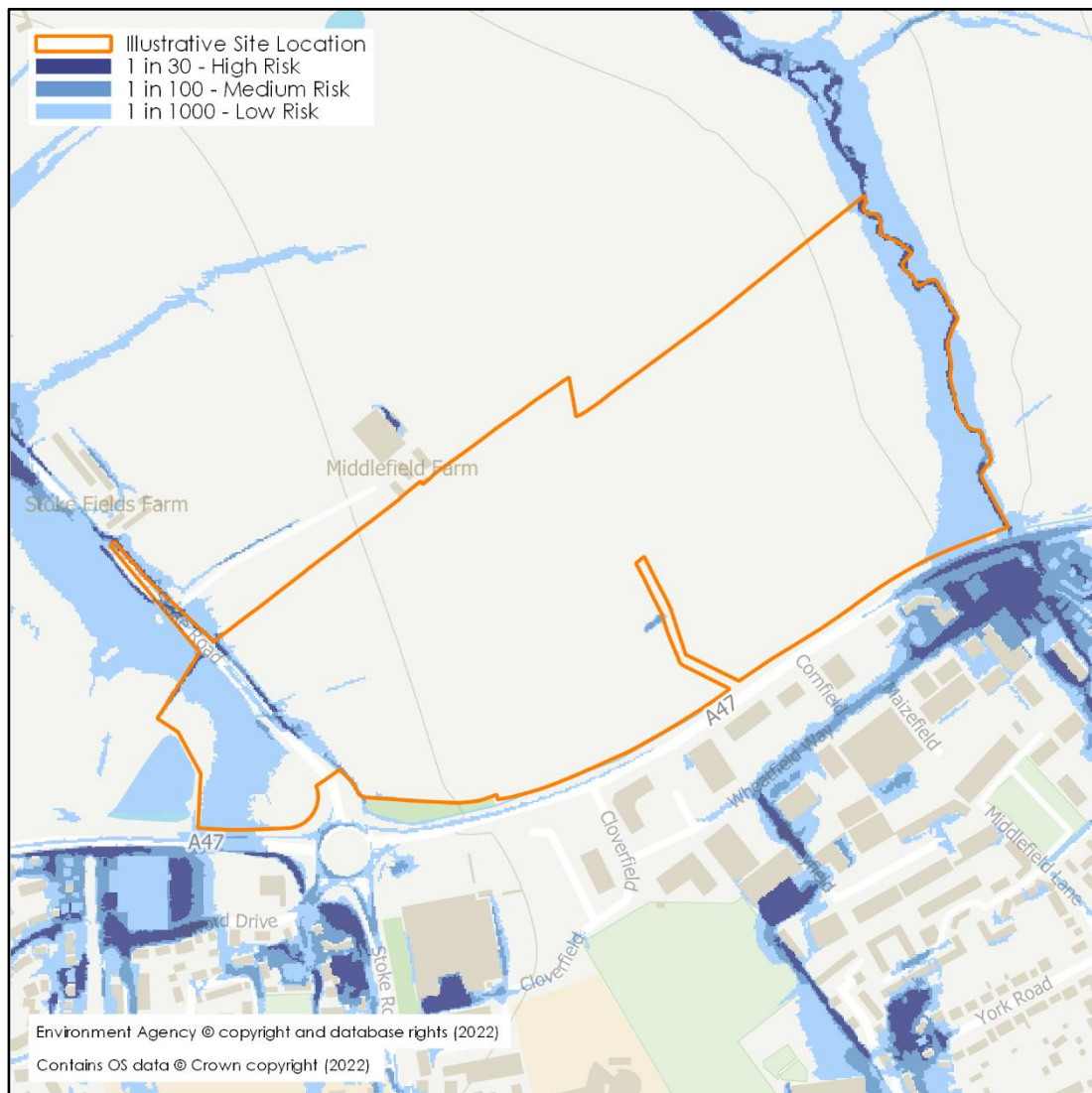


Figure 1.6: EA Risk of Flooding from Surface Water

- 1.26 Given that surface water flooding is also predicted to overtop Normandy Way at the UOW (R1), out of bank flooding is also predicted within the site at the eastern boundary for the larger magnitude (1 in 1000-year) storm event. Notable surface water flooding is predicted within urban areas of Hinckley upstream of both the UOW (R1) and the western ditches, which aligns with the capacity issues of the existing sewer network (as identified by Severn Trent Water). However, the surface water mapping does not explicitly represent culverts and structures and therefore is expected to provide a conservative representation of surface water flood risk at the site.

Other Sources of Data

- 1.27 The following additional datasets were used within the hydraulic modelling exercise:
- EA Light Detection and Ranging (LiDAR) 2020 1m Digital Terrain Model (DTM).
 - Topographical survey (reference: 42117_T_REV0), undertaken in November 2021.
 - Cross-sectional Watercourse Survey, undertaken in February 2022 (**Appendix 1**).

- Photographs and observations from the site visit undertaken in January 2022 by BWB Consulting.
- A hydrological assessment of flood flows undertaken by BWB Consulting (**Appendix 2**).

Assumptions and Limitations

1.28 Several assumptions were made during the study which may lead to implications on the modelled results. However, the study has been based on the data available at the time of writing. The key assumptions and limitations are as follows:

- The modelling exercise has made use of the available data at the time of construction and simulation. The model represents the floodplain and channel conditions at the time of survey.
- The model contains no formal representation of the conveyance within minor watercourses or ditches other than that captured by the model grid and within the 1D model domain.
- The 2m resolution of the model may negate any small-scale topographic features, although all the significant features are believed to have been captured.
- Some of the floodplain levels are derived from LiDAR which has limited accuracy ($\pm 0.15\text{m}$). however, this is considered to be sufficient for the purpose of this study.
- The bare earth DTM does not include for the presence of walls, buildings or other structures. Buildings have been modelled at ground level with an elevated roughness in line with best practice.
- The modelling exercise has been undertaken to produce a good representation of flood risk mechanisms in and around the study site. It has not been designed to accurately map flooding in the wider catchment.
- An assessment of OS mapping, LiDAR and sewer records was undertaken to determine the extent of the upstream catchment areas that drain to the watercourse and ditches that have been assessed as part of this study.
- The culvert at the end of R4 has been assumed to discharge beneath Stoke Road into R2 so that levels maintain a constant gradient. A CCTV survey will be required to confirm the exact culvert outlet location.
- Sewer manhole cover levels have been based off Severn Trent Water sewer records in the catchment upstream of the UOW (R1). An alternative approach has been adopted in the catchment upstream of the ditches, whereby cover levels are determined off the respective ground level informed by the 1m LiDAR data at this location. This was to overcome off-site model instabilities.
- It is assumed that Severn Trent Water sewer records can be relied upon to represent the network surrounding the site and no CCTV survey has been undertaken at this time to verify the outputs.
- All manholes are assumed to have a diameter of 0.5m with the diameter of any pipes taken from Severn Trent Water Sewer records.
- It is assumed that all sewers are clear from any blockages/sedimentation.
- Only the primary trunk sewer runs have been represented within the model. No secondary networks or private drainage have been included which may alter the timing and distribution of flows.

2. HYDROLOGY

Flood Flow Estimation

- 2.1 A hydrological review of the catchment was undertaken using Flood Estimation Handbook (FEH) methodologies to estimate peak flood flows and derive an appropriate hydrograph shape. This was undertaken in relation to the EA's latest guidance⁵. This assessment is documented within **Appendix 2**. For the purpose of the hydrological assessment, all features have been given a UOW site code prefix as detailed within **Table 2.1**.

Table 2.1: Naming Convention

Modelling Naming Convention	Hydrology Naming Convention
UOW (R1)	UOW001
Ditch (R2)	UOW002
Ditch (R4)	UOW003

- 2.2 In summary, there was no hydrometric data available in the area to inform the hydrological analysis. Therefore, the industry standard FEH statistical method and Revitalised Flood Hydrograph (ReFH2.3) rainfall-runoff model were both reviewed, and a comparative analysis undertaken.
- 2.3 The final choice of peak flows for input into the model for the UOW was the FEH Statistical Method as it benefits from an up-to-date flood peak dataset, using growth curves from hydrologically similar catchments to derive a growth curve. The Statistical Method also benefits by avoiding the need to make assumptions about factors such as rainfall duration, time of concentration and the nature of the design flood, unlike the ReFH2 method.
- 2.4 ReFH2 was used to provide a hydrograph shape for the model inflows for the UOW (R1), scaled to the Statistical peak.
- 2.5 The final choice of peak flows for input into the model for the ditches is the ReFH2 Method, due to the influence of sewers at the upstream extent of the watercourses.
- 2.6 A full record of the hydrological analysis can be found in **Appendix 2**.
- 2.7 The final inflows incorporated into the model are summarised within **Table 2.2**. **Figure 2.1** demonstrates how the flows will be applied to the model. For UOW001, the model extent was located further upstream than the flow estimation location and therefore the flows detailed in **Table 2.2** were pro-rated to cover a catchment that would drain to the extent of the watercourse that has been modelled.

⁵ Flood Estimation Guidelines 197_08 (Environment Agency, June 2020)

Table 2.2: Adopted Peak Flood Flows

Return Period Event (Yrs)	Annual Exceedance Probability (AEP)	Catchment Peak Flow – UOW001 (m ³ /s)	Catchment Peak Flow – UOW002 (m ³ /s)	Catchment Peak Flow – UOW003(m ³ /s)
1 in 2	50%	0.6	0.3	0.2
1 in 5	20%	0.8	0.5	0.2
1 in 10	10%	1.0	0.6	0.3
1 in 20	3.3%	1.2	0.7	0.3
1 in 50	2.0%	1.5	0.8	0.4
1 in 75	1.3%	1.7	0.9	0.5
1 in 100	1.0%	1.8	1.0	0.5
1 in 200	0.5%	2.2	1.3	0.6
1 in 1000	0.1%	3.5	2.0	1.0

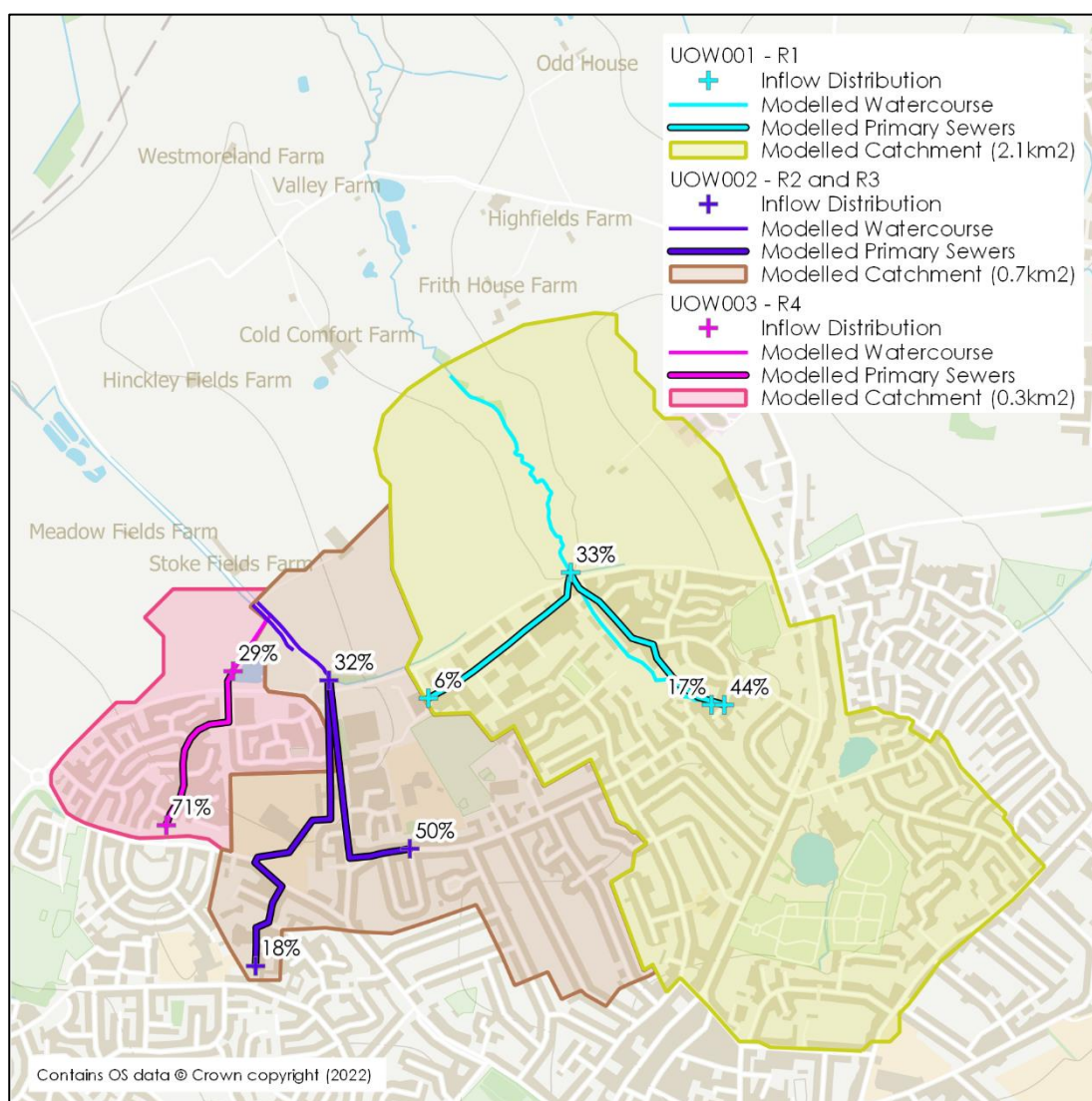


Figure 2.1: Distribution of Model Inflows

Climate Change

- 2.8 Predicted future change in peak river flows caused by climate change are provided by the EA within their online guidance⁶, with a range of projections applied to regionalised 'River Basin Districts'. These districts are further split into 'Management Catchments'.
- 2.9 The study area falls within the Tame Anker and Mease Management Catchment of the Humber River Basin District. **Table 2.3** identifies the relevant peak river flow allowances.

Table 2.3: Peak River Flow Allowance for the Tame Anker and Mease Management Catchment

Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2125)
Upper End	24%	30%	51%
Higher Central	15%	17%	30%
Central	10%	11%	22%

- 2.10 To estimate the potential future design floodplain under a range of scenarios, the Central climate change allowance for the 2080s will be applied to the 1 in 100-year flood flows. The design event is subsequently the 1 in 100-year +22% climate change (CC) event.

⁶ Environment Agency, Flood risk assessments: climate change allowances: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1>

3. THE HYDRAULIC MODEL

Software and Solver

- 3.1 A combination of TUFLOW version 2020-10-AC-iDP and 2020-10-AB-iDP was used for all model runs. TUFLOW's Classic solver was used.
- 3.2 TUFLOW's built in 1D component, ESTRY, was used to model the 1D domain/channel.

The 1D Domain

Extent

- 3.3 The 1D domain for the western ditches begins from within the site boundary. The ditches are represented within the 1D domain until the downstream boundary. A Model Schematic is included as **Appendix 4**.
- 3.4 The 1D domain for the UOW (R1) begins upstream of the site, to the rear of the dwellings located along Nelson Drive. The majority of the channel is represented within the 1D domain, however the first 400m of watercourse is modelled within the 2D domain.
- 3.5 The public sewers, as shown on Severn Trent Water sewer records, have been identified as discharging to the eastern UOW and western ditches. Accordingly, relevant areas of the public sewer network were represented within the 1D domain. Only the trunk sewers that drain towards to the watercourses/ditches were incorporated within the model. No private sewer networks or secondary networks have been included within the model.
- 3.6 The inclusion of the main sewer runs in the model provides a representation of how the flows are routed through the drainage system before outfalling to the watercourse and ditches. In addition, this allows for an assessment of constraints introduced by the insufficient capacity of the sewer network upstream of the site.
- 3.7 In order to represent the interaction between the subsurface sewer network and the surface, manhole locations (as identified by Severn Trent Water sewer asset records) were represented in the model using a "1d_pits" layer.
- 3.8 Each manhole was provided an assumed diameter of 0.5m. The surface levels in the sewer network associated with the UOW (R1) were defined by cover levels provided by Severn Trent. For the sewer network upstream of the western ditches, 1m LiDAR data was used to inform the manhole surface levels. This different approach was considered necessary to overcome off-site model instabilities that were caused by a disagreement between the Severn Trent cover levels and 2D ZC levels of surrounding cells, as defined by the 1m LiDAR.
- 3.9 The model domain is shown in **Figure 3.1** and as a Model Schematic included as **Appendix 4**.

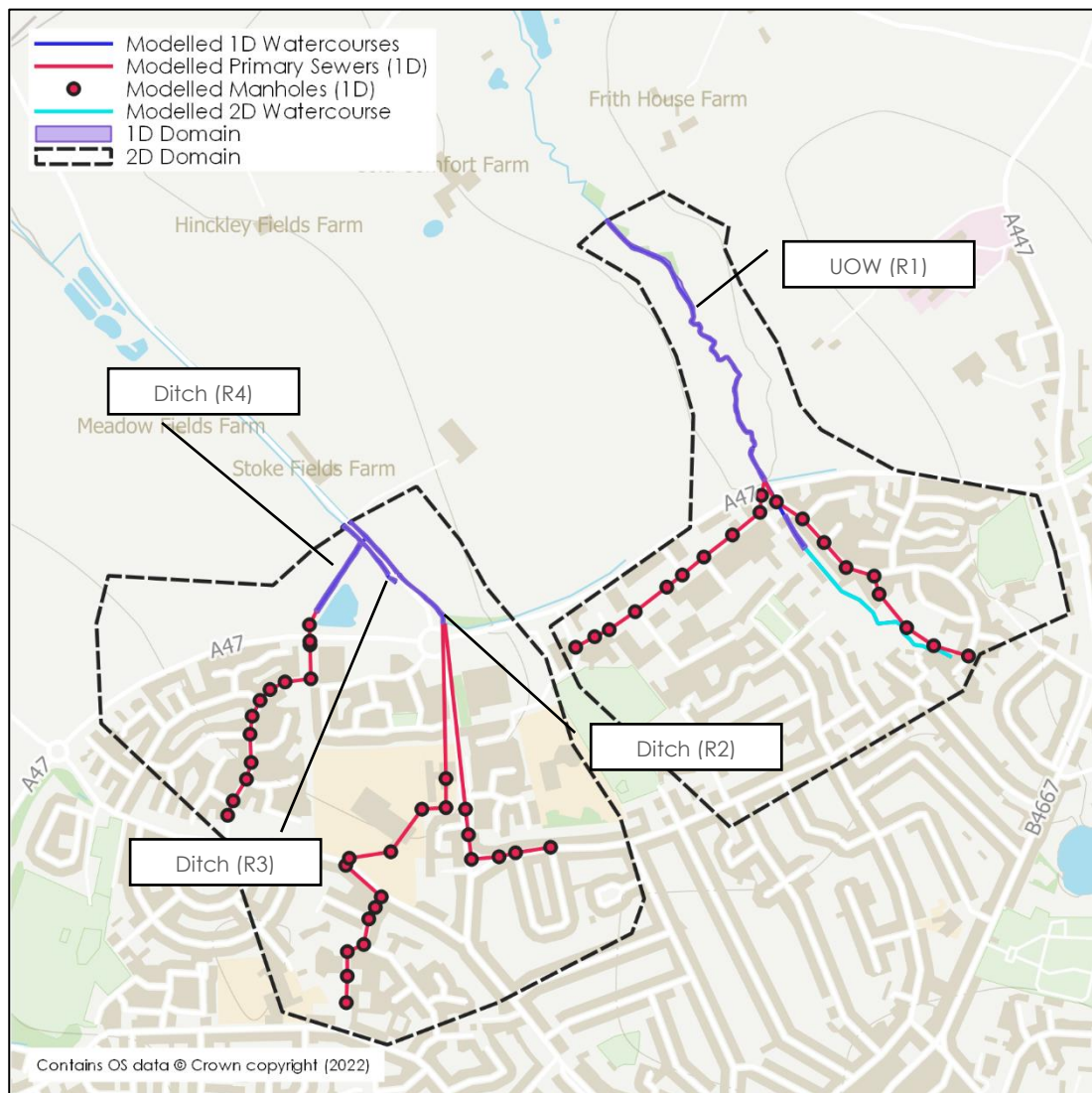


Figure 3.1: Modelled Watercourses, Sewers and Domain Extents

Channel Geometry

- 3.10 The river channel geometry is based on a new watercourse survey carried out by BWB Consulting in February 2022. The survey also captured hydraulic structures that were present such as bridges and culverts.
- 3.11 The maximum distance between cross sections is 125m. However, sections are more generally spaced 45m-80m apart. The river channel survey is available as **Appendix 1**.
- 3.12 The channel sections were truncated at top-of-bank from survey data, at what would be the interface with the 2D domain.

Hydraulic Roughness

- 3.13 Hydraulic roughness has been represented using the Manning's n coefficient. The values applied are based on those stipulated in the literature, using Chow (1959)⁷. This study documents appropriate values based on channel bed material, sinuosity and presence of vegetation.
- 3.14 The guideline values are chosen using engineering judgement, based on photographs of the channel condition taken at the time of survey. Each cross section has a Manning's roughness value applied in the same way as the channel geometry and is read into TUFLOW within a CSV file.
- 3.15 The bed of the eastern UOW and ditches were generally clean and winding with pools and riffles and light bank vegetation. The bank vegetation varied across the sections, however predominately areas were considered to be either highly vegetated around hedgerows with lower roughness values assigned where grass was present. Some examples are highlighted in **Table 3.1** below.

Table 3.1: Manning's n examples

Model ID	Values chosen and description	Photograph
UOW001_00769	0.04 Main Channels Clean, but winding with pools and riffles, light bank vegetation	

⁷ http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

Model ID	Values chosen and description	Photograph
R4_00023	0.03 Floodplains Grass, short	
R2_00077	0.06 Floodplains Trees – medium density with sprouts	

Hydraulic Structures

- 3.16 A number of hydraulic structures were represented in the 1D domain, the data for which was collected during the watercourse survey.
- 3.17 In total, 6 circular culverts and 2 irregular culverts were included in the model, the details of which are included as **Appendix 3**.

Boundary Conditions

- 3.18 Boundary conditions were applied to the 1D domain to both allow flow in and out of the model.
- 3.19 QT (flow vs time) boundaries were used to represent the fluvial inflows (**Section 2**) as hydrographs. These consisted of point inflows at the upstream extents of the watercourses and sewers and at the downstream extent of any intervening

topography (i.e. Normandy Way). **Figure 2.1** shows where these boundaries were applied.

- 3.20 A HT (water level vs time) boundary was applied at the downstream limit of the 1D domain. This was set to 104.77mAOD for the UOW (R1) which is the surveyed top of bank at the downstream cross section (UOW001_00702), 103.85mAOD for R2 which is the surveyed water level at the downstream cross section (R2_00000) and 104.05m AOD for R3 which is between the top of bank and bed level of the downstream cross section (R3_00000).

1D/2D Links

- 3.21 The 1D channel was linked to the floodplain using "HX" links. These transfer the calculated water level from the 1D cross sections into the 2D floodplain, providing that the water level is above the level of the cell that the HX link is located in. Therefore, HX links should be digitised along the top of bank of the watercourse visible in LiDAR data or along the crest of any embankments if present.
- 3.22 In order to represent the interaction between the subsurface sewer network and the 2D domain, manholes were represented in the model using a "1d_pits" layer. A "SXZ" command is utilised in the 1d_pits layer to allow water to spill from the manhole into the 2D domain and vice versa.
- 3.23 The average modelled width of the channel was approximately 6-8m.

The 2D Model Domain

Extent and Active Area

- 3.24 The main influence on the 2D domain extent is generally the expected width of the floodplain, meaning that it should be large enough to allow for flows to be routed through the floodplain, where necessary, and so that no "glass walling" occurs within the boundary of the model domain.
- 3.25 The river channel was deactivated to ensure that it was modelled in the 1D domain. This deactivated area may appear fragmented in places where the deck of a structure is modelled in the 2D domain. The active area is displayed in **Figure 3.1** and is shown in the Model Schematic included as **Appendix 4**.

Grid Size and Orientation

- 3.26 The grid cell size should be chosen in order to sufficiently represent the average width of the modelled channel and its ability to capture key floodplain topographic features.
- 3.27 The selected grid size of 2m provides a high enough resolution to capture the capacity of the channel (6m width = 3 number of 2m cells) as well as provide the representation of key floodplain features to an appropriate level of detail.

- 3.28 The orientation of the grid is important for flow routing as flow cannot pass to the neighbouring cell via its corner, only via the cell sides. Therefore, the location line (2d_loc) was drawn to orientate the grid in the predominant direction of flow (southeast to northwest).

Floodplain Roughness

- 3.29 Floodplain roughness is defined by the Manning's n coefficient, as per the 1D domain. However, the method in which it is applied differs.
- 3.30 A global roughness value is set based on the predominant land use (long grass) in the catchment. This is then supplemented by a series of polygons, based on spatial variation in land use, which applies values, where appropriate, from a variety of sources such as OS MasterMap data and aerial imagery. These are linked to a coefficient listed in a TUFLOW Materials File (TMF).
- 3.31 The values applied for different land use types are listed in **Table 3.2**.

Table 3.2: Floodplain Roughness Values

Land Use Type	Manning's n Coefficient
Long grass	0.035
Short grass	0.030
Roads	0.015
Woodland	0.060
Buildings	0.500

Floodplain Topography and Amendments

- 3.32 The general floodplain topography is based on the latest available LiDAR data (flown in 2020), which was downloaded from the DEFRA Open Survey website at a 1m resolution.
- 3.33 The following amendments to the base topography were made:
- River bank levels were reinforced through the use of a 'THICK' z-line. Bank elevations were provided at intervals along the z-line. The levels were informed by surveyed cross section data, topographical survey and LiDAR data (where survey data was unavailable).
 - Stoke Road was reinforced through the use of a z-shape. Road elevations were provided at intervals along the z-shape. The levels were informed by topographical survey and LiDAR (where survey was unavailable).
 - Approximately 400m of the eastern UOW was reinforced upstream of Nelson Drive through using a z-shape, with a width of 3, given that no watercourse survey data was available. The bed level of the UOW was reinforced from LiDAR at intervals

along the z-shape. Spot checks were then undertaken on the model grid to ensure a constant positive gradient towards the 1D domain.

Floodplain Structures

- 3.34 There were no floodplain structures within the model. All hydraulic structures were in line with the channel and hence modelled in the 1D domain.

Boundary Conditions

- 3.35 Boundary conditions within the 2D domain are often used to prevent “glass walling” at the downstream end of the model through use of a “HQ” boundary. This is a flow vs stage relationship automatically defined in TUFLOW when the user inputs a slope value, to allow water to flow out of the model.
- 3.36 A “HQ” boundary was applied to the downstream extent of the model and adjacent to any sewers located near to the 2D domain. The slope in the “HQ” boundary was calculated by assessing the fall in floodplain ground levels over a set distance. The fall in ground levels was then divided by the distance measured to determine a slope value.

Initial Water Levels

- 3.37 Initial water levels are often applied to features such as lakes, ponds or canals to represent them containing water of a nominal depth at the start of the model run.
- 3.38 An initial water level was applied at each cross section. The value was taken from the surveyed water level.

Calibration/Verification

- 3.39 A lack of detailed flow or level data for the catchment meant that there was limited opportunity to calibrate the model.
- 3.40 Due to the lack of documentation on previous historical instances of flooding, the model cannot be verified against historic events. A conservative approach adopted to the model build mitigates this.

Stability, Warnings and Messages

- 3.41 TUFLOW has a number of indicators available to assess the stability of a model. These differ slightly between the Classic and HPC solver (the Classic solver was used for this model). The following indicators were checked to ensure the model was performing as expected:
- **Stage and flow time series** – A number of spot checks should be completed to ensure that conveyance through the channel is as expected and that both the stage and flow time series are reasonably smooth, particularly around the study area.

- **1D negative depths** – Significant negative depths indicate that instabilities are present.
- **Cumulative Mass Error** – A value of +/-1% is considered acceptable.
- **Velocities** – Unusually high velocities or circulating vectors are usually a sign of instabilities.

3.42 The time series graphs were reviewed along the modelled reaches and no significant issues were present that could compromise results at the site. The river channel water levels were shown to peak at approximately 6 hours into the event along the eastern UOW, 5 hours into the event along Reach 2 and 3.5hrs into the event along Reach 4.

3.43 No 1D or 2D negative depths were reported.

3.44 The baseline simulations reported a peak mass error within +/- 1% except for the very high magnitude events for the western ditches. The maximum peak mass error found within the model simulations was -1.05% for the 1 in 100-year +51%CC event. This occurs approximately 3-5 hours after the peak of the flood event and the mass error drops back into the accepted range within 15 mins of reaching this peak value. It should be noted that in both design events (1 in 100-year +22%CC) the mass error peaked within +/- 1%. Therefore, although not ideal, this mass error can be considered insignificant.

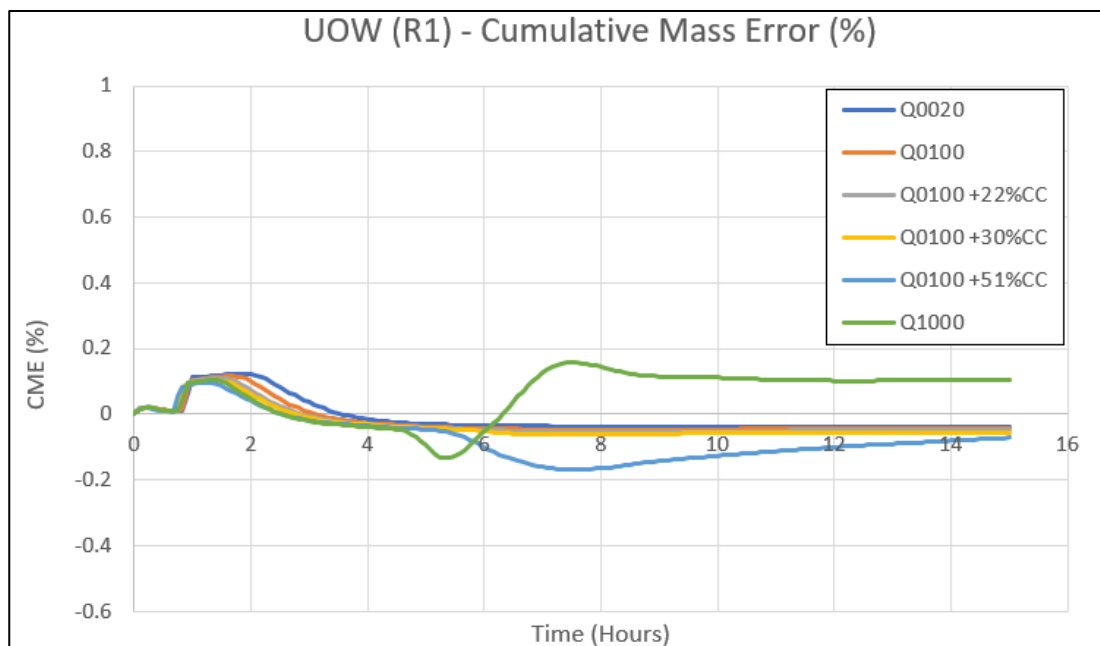


Figure 3.2: UOW (R1) Cumulative Mass Error Plots (Baseline)

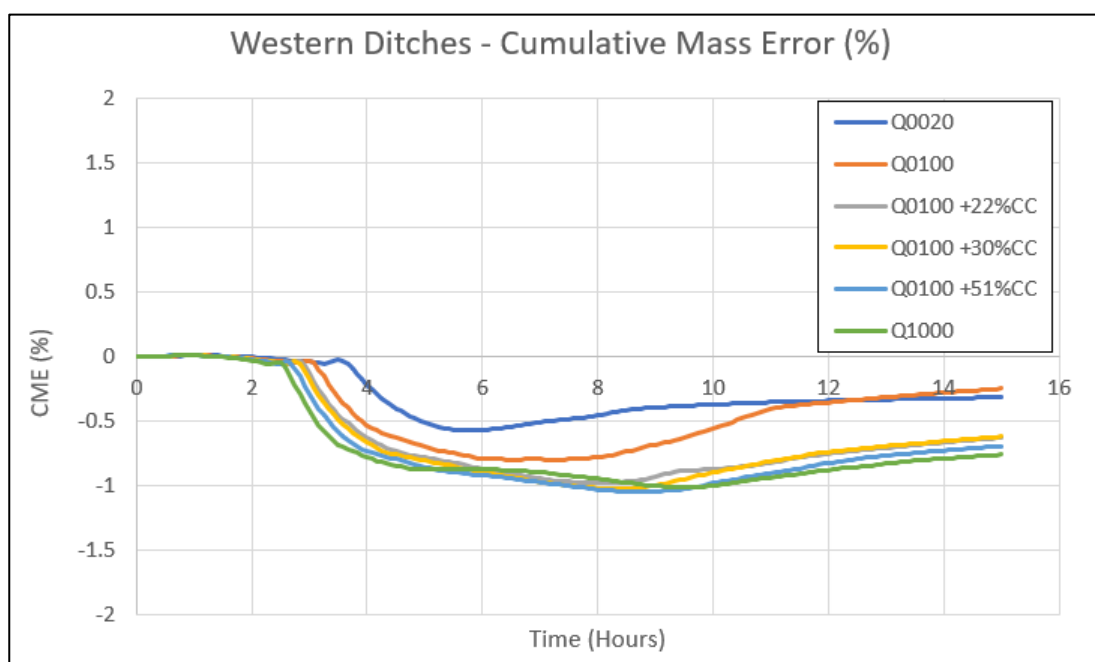


Figure 3.3: Western Ditches Cumulative Mass Error Plots (Baseline)

3.45 There were no warnings recorded during the simulation.

Model Runs

3.46 In order to achieve the study objectives, the simulations summarised in **Table 3.3** were completed.

Table 3.3: Model Runs

Model Geometry	Return Periods	Comments
Baseline	1 in 20-Year 1 in 100-Year 1 in 1000-Year 1 in 100-Year +22%CC 1 in 100-Year +30%CC 1 in 100-Year +51%CC	Representative of 'as surveyed' conditions
Roughness +20%	1 in 100-Year	Floodplain, channel and structure roughness increased by 20%
Roughness -20%	1 in 100-Year	Floodplain, channel and structure roughness decreased by 20%
Downstream Boundary +	1 in 100-Year	Downstream boundary water level decreased by 100mm and 20% increase of gradient at HQ boundaries
Downstream Boundary -	1 in 100-Year	Downstream boundary water level increased by 100mm and 20% decrease of gradient at HQ boundaries

4. BASELINE RESULTS

- 4.1 The baseline floodplain extents are provided in **Appendix 5** and are summarised below.

UOW (R1)

- 4.2 The floodplain extents and levels at selected locations for the UOW (R1) are illustrated in **Figure 4.1** and **Table 4.1**.

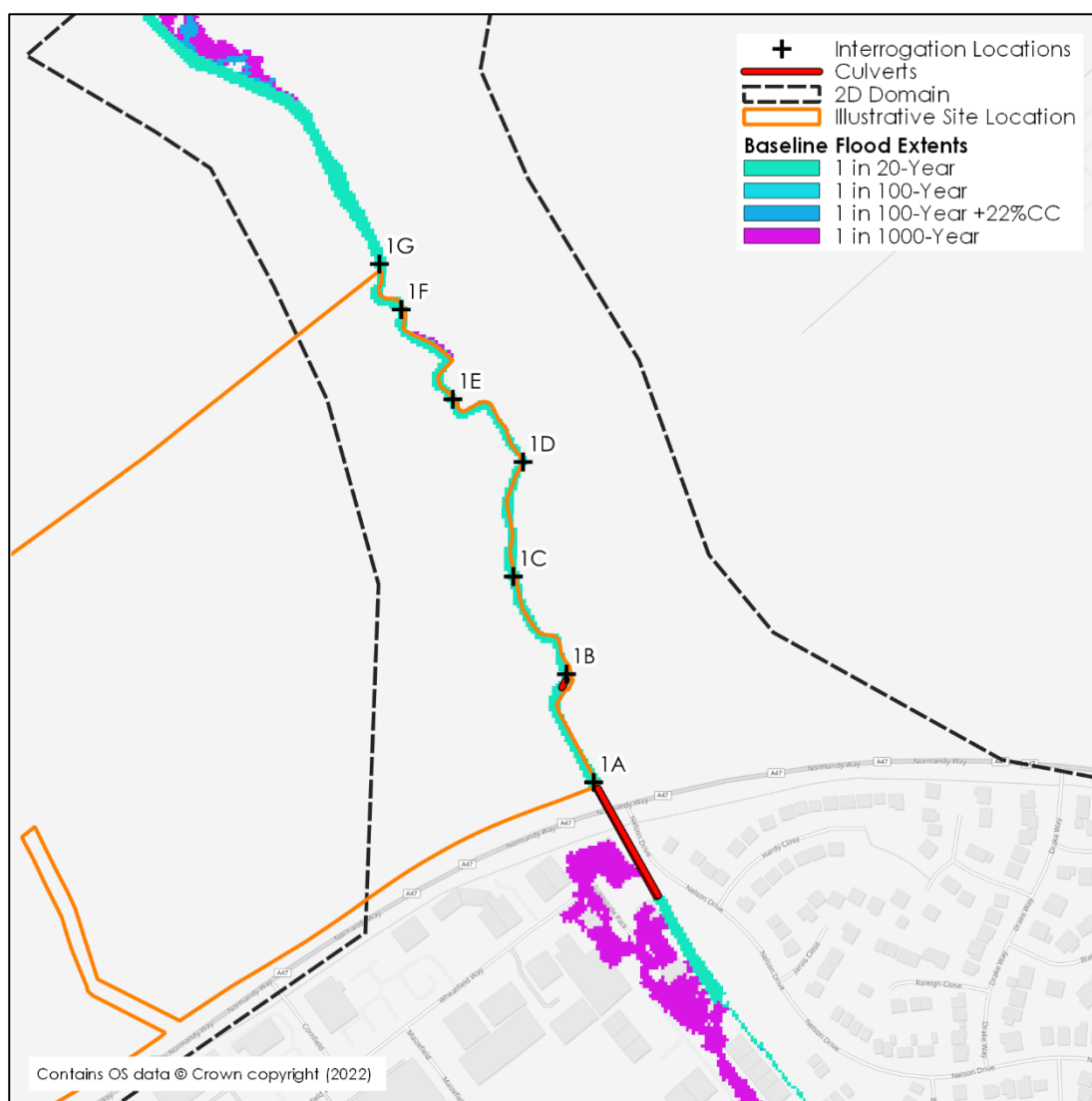


Figure 4.1: UOW (R1) Flood Extents

Table 4.1: UOW (R1) Peak Flood Levels (mAOD)

ID	1 in 20-Year	1 in 100-Year	1 in 100-Year + 22%CC	1 in 1000-Year
1A	108.12	108.20	108.26	108.43

1B	107.23	107.41	107.51	107.73
1C	107.08	107.25	107.34	107.55
1D	106.84	107.00	107.08	107.27
1E	106.51	106.66	106.73	106.91
1F	106.12	106.28	106.35	106.51
1G	105.97	106.10	106.15	106.27

Flood Mechanisms

- 4.3 The flood mechanisms for the UOW (R1) are shown in **Figure 4.2** and are summarised below.

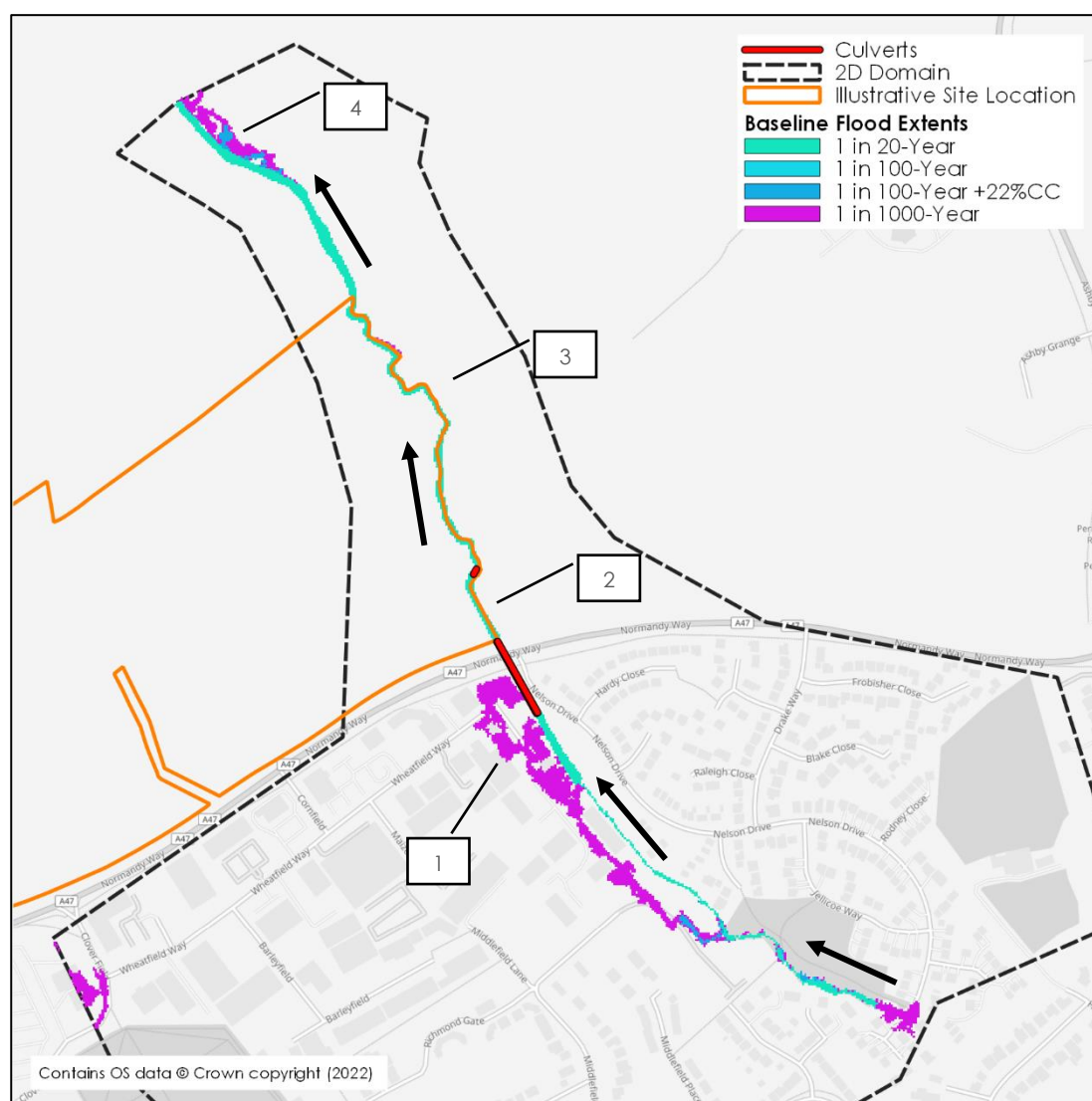


Figure 4.2: UOW (R1) Flood Mechanisms

1 – The UOW enters the site via twin 0.5m diameter culverts beneath Normandy Way. The structure is shown to have insufficient capacity to convey peak flows during the 1 in 1000-year event. Subsequently, the pipe becomes surcharged, resulting in localised flooding predicted immediately upstream.

2 – There are notable differences between the modelled 1 in 1000-year flood extent and the 1 in 1000-year surface water (low risk scenario) extent (see **Figure 1.6**). The surface water mapping does not explicitly represent culverts and structures and therefore is expected to provide a conservative representation of surface water flood risk at the site. The hydraulic model has represented the culvert (2 x 0.5m diameter pipes) beneath Normandy Way which has sufficient capacity to convey flows through the site for events up to the 1 in 1000-year. Subsequently, there is a reduction in flood extent when compared to the surface water mapping.

3 – As the UOW flows adjacent to the site, maximum water levels remain in-channel. Subsequently, the proposed residential development is located outside of all modelled flood extents from this watercourse.

4 – Downstream of the site, flood events in excess of the 1 in 100-year event are predicted to exceed the channel capacity, with evidence of overtopping along the right bank.

Western Ditches (R2, R3 and R4)

- 4.4 The floodplain extents and levels at selected locations for the western ditches (R2, R3 and R4) are illustrated in **Figure 4.3** and **Table 4.2**.

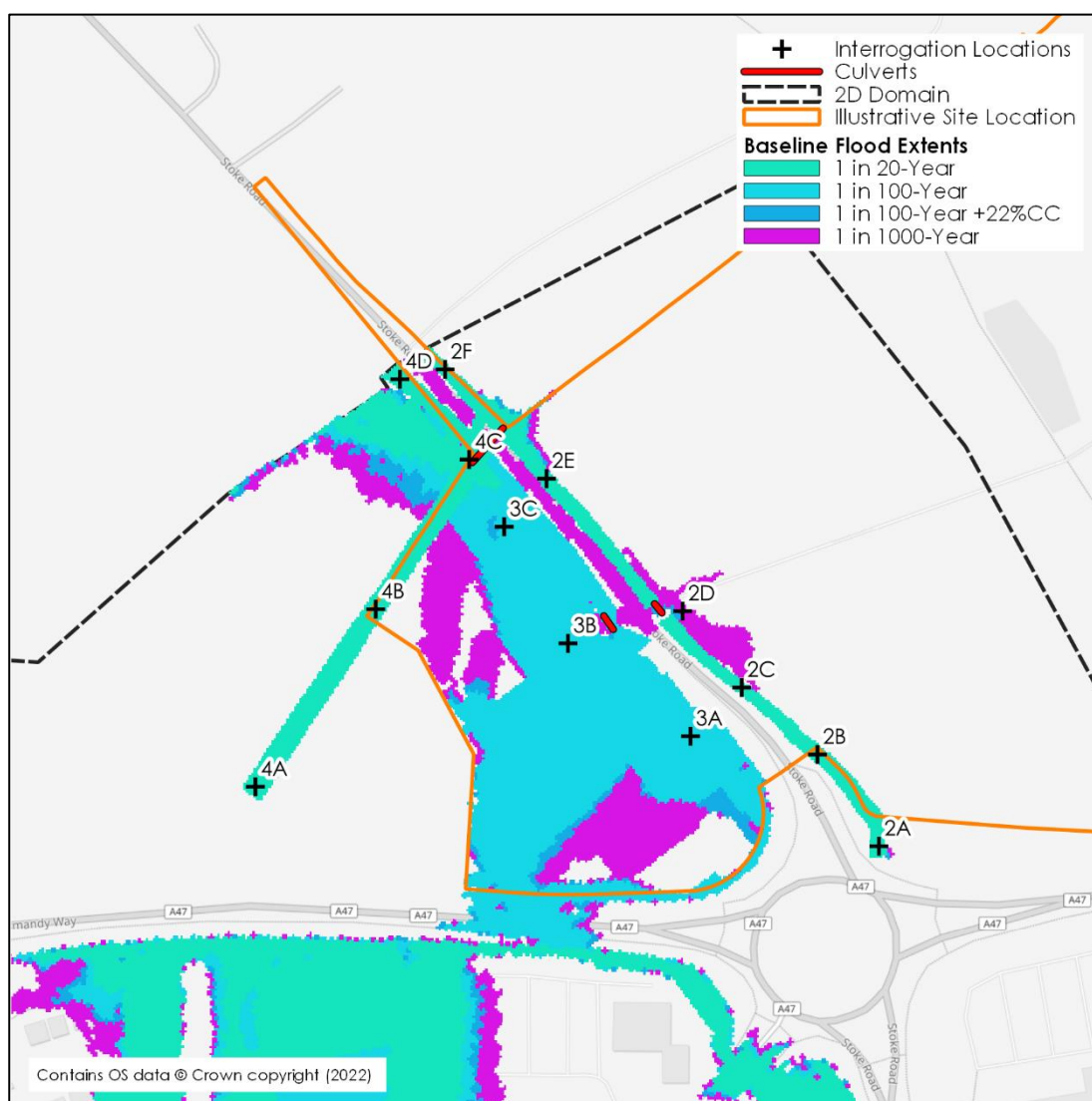


Figure 4.3: Western Ditches (R2, R3 and R4) Flood Extents

Table 4.2: Western Ditches (R2, R3 and R4) Peak Flood Levels (mAOD)

ID	1 in 20-Year	1 in 100-Year	1 in 100-Year + 22%CC	1 in 1000-Year
2A	105.71	105.81	105.89	106.00
2B	105.48	105.66	105.78	105.88
2C	105.36	105.58	105.72	105.81
2D	-	-	-	105.74
2E	104.57	104.63	104.66	104.75
2F	104.01	104.02	104.03	104.04
3A	-	105.39	105.40	105.40

3B	-	105.13	105.13	105.14
3C	-	104.72	104.73	104.75
4A	104.57	104.62	104.66	104.75
4B	104.54	104.58	104.60	104.66
4C	104.54	104.57	104.59	104.64
4D	104.10	104.11	104.12	104.12

Flood Mechanisms

- 4.5 The flood mechanisms for the western ditches (R2, R3 and R4) are shown in **Figure 4.4** and are summarised below.

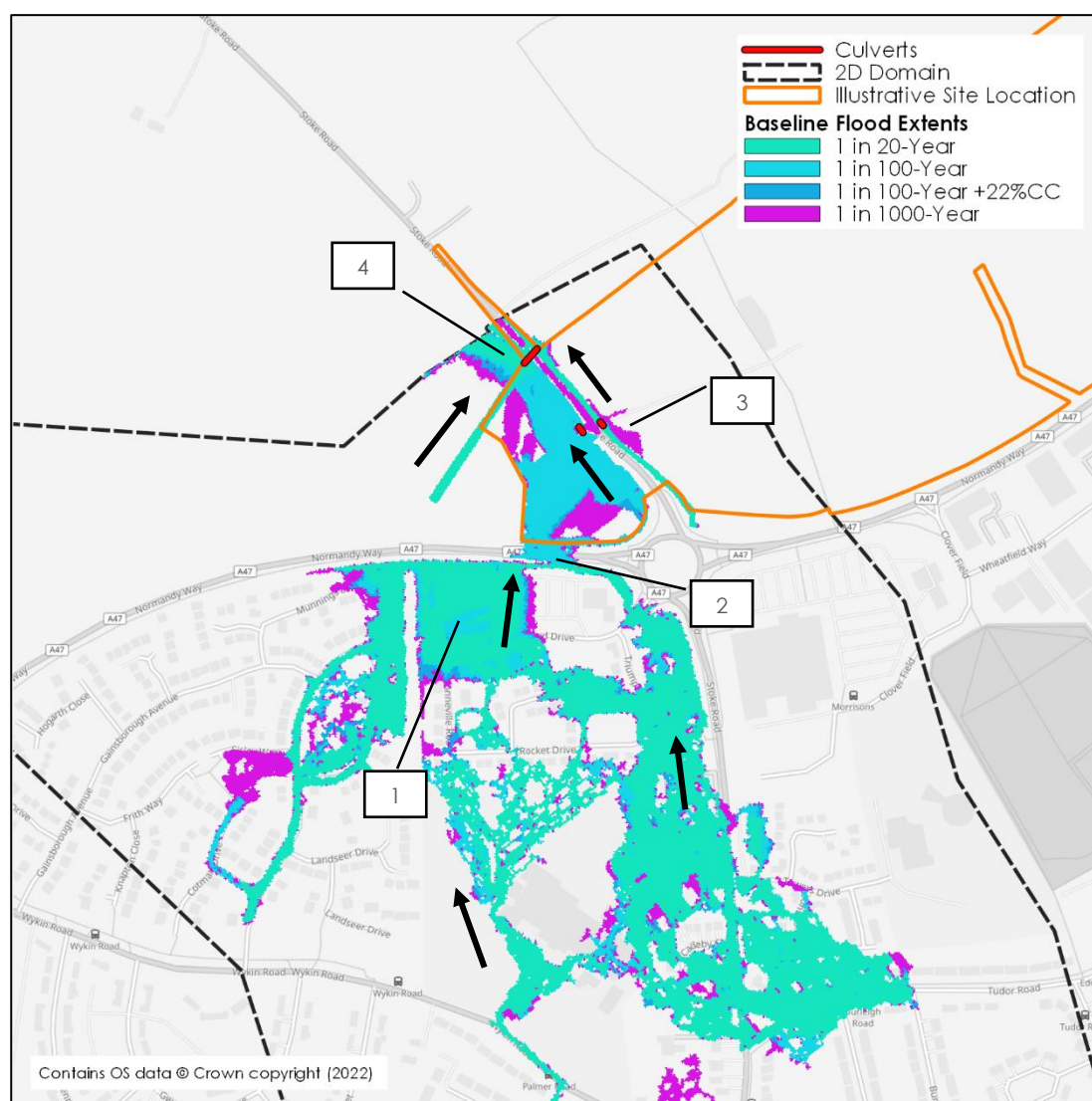


Figure 4.4: Western Ditches (R2, R3, R4) Flood Mechanisms

1 – The manholes represented within the upstream Severn Trent sewer network are predicted to surcharge during all events including the 1 in 20-year event. This subsequently results in out of bank flooding predicted upstream of Normandy Way for all modelled return periods. This aligns with known capacity issues in this area that have been raised by Severn Trent Water at the time of consultation.

2 – As a consequence of flood waters accumulating upstream of Normandy Way, the model predicts that the A47 will be overtopped during the 1 in 100-year return period and larger magnitude events. It is subsequently predicted that flood waters will be conveyed into the land parcel west of Stoke Road.

3 – During the 1 in 1000-year event, out of bank flooding is predicted at low levels of the eastern land parcel immediately adjacent to R2. This occurs due to the 600mm diameter culvert having insufficient capacity to convey peak flows for the 1 in 1000-year event without the right bank being overtopped. Ground levels on this bank are lower due to an incoming hedgerow with an associated drainage ditch.

4 - Flows also exceed channel capacity where R4 is assumed to converge with R2. This is understood to be associated with a restrictive irregular culvert and a topographical depression adjacent to the road between R3 and R4, which overland flows subsequently pool within.

5. SENSITIVITY TESTING

- 5.1 To account for seasonal variations in vegetation and to ensure the robustness of boundary conditions, a series of sensitivity tests were conducted using the 1 in 100-year flood return period event. The difference in peak water level and floodplain extent between the sensitivity test scenarios and the 1 in 100-year baseline event are mapped in **Appendix 6**.
- 5.2 Robust sensitivity analysis also provides improved confidence in the model outputs, particularly in absence of calibration data.

Downstream Boundary

- 5.3 The modelled 1D downstream boundary is a HT boundary set in accordance with the top of bank or water level at the time of survey. The boundary was adjusted by 100mm within the sensitivity tests. The 2D HQ boundary slopes were also updated by 20%.
- 5.4 A 100mm increase in the HT boundary level and an increase in the slope gradient (20%) at the HQ boundaries leads to a decrease in peak flood level towards the downstream boundary of the UOW (R1). There is no change in flood levels or extents adjacent to the site. There are localised changes in peak flood level along the western ditches and a small, localised increase in modelled flood extent. The depths within the site boundary are shown to increase by 60mm in this area, as shown in **Appendix 6**.
- 5.5 A 100mm decrease in the HT boundary level and a reduction in the slope gradient (20%) at the HQ boundaries leads to an increase in peak flood level towards the downstream boundary of the UOW (R1). There are no change in peak flood levels or flood extents adjacent to the site. There are localised changes in peak flood level along the western ditches and a small, localised decrease in modelled flood extent. The depths within the site boundary are shown to decrease by 90mm in this area, as shown in **Appendix 6**.
- 5.6 Although there are differences in peak levels towards the downstream boundary, these effects do not propagate a significant distance upstream towards the site. This therefore indicates that the model results are not sensitive to changes to the downstream boundary.

Roughness Coefficients

- 5.7 The modelled roughness coefficients were determined from aerial imagery and site photographs. Increasing and decreasing the roughness values in the channel and structures as well as on the floodplain will test how seasonal variation and maintenance regimes may affect the flood risk posed to the development.
- 5.8 A 20% increase in Manning's n roughness coefficient, representative of a period without maintenance, leads to increased peak flood levels and floodplain extents across the model domain. Adjacent to the site, peak flood levels are expected to increase by up to 90mm when compared to the baseline results.

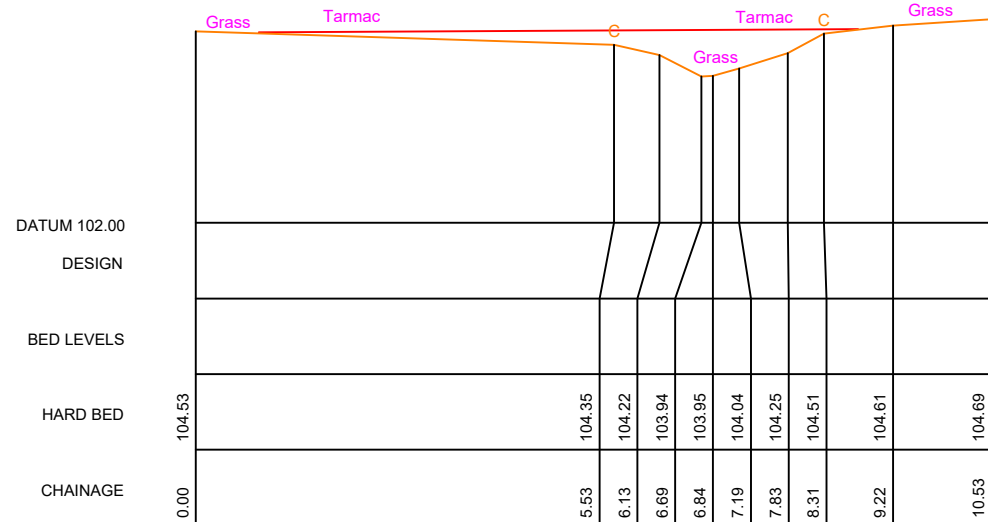
- 5.9 This is to be expected given that an increase in roughness values across the floodplain will be associated with greater frictional forces against the flow of water. Subsequently, more flood water would likely be retained on the floodplain during these conditions, therefore resulting in a general increase in flood levels. Similarly, greater in-channel Manning's values would be expected to increase water levels as a rougher channel would detrimentally impact flows.
- 5.10 A 20% decrease in Manning's n roughness coefficient, representative of a period with maintenance, leads to reduced peak flood levels and floodplain extents across the model domain. Adjacent to the site, peak flood levels are shown to decrease by up to 100mm when compared to the baseline results.
- 5.11 This is to be expected, as the reduced roughness will increase the conveyance of the floodplain and culverts, allowing water to flow more freely through the system.

6. SUMMARY & RECOMMENDATIONS

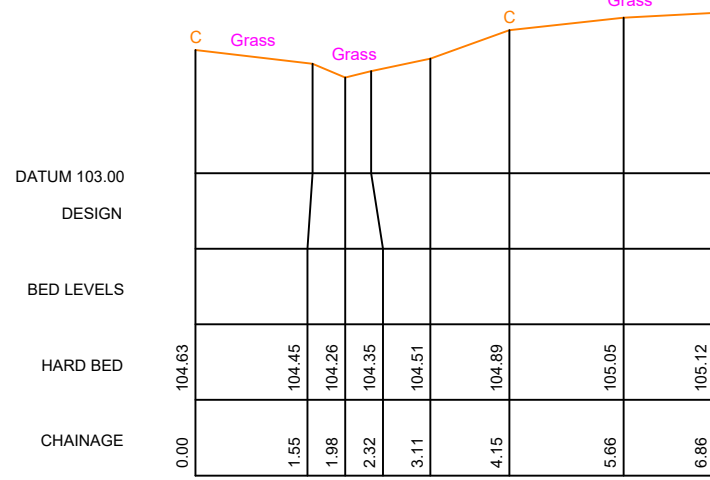
- 6.1 Please note that this conclusion should be read in conjunction with the study limitations and assumptions in **Section 1**.
- 6.2 BWB Consulting Ltd has been commissioned by Richborough Estates Limited and Mr & Mrs Adcock to undertake a site-specific hydraulic modelling exercise of an Unnamed Ordinary Watercourse (UOW) and a series of ditches to support a residential development to the North of Hinckley.
- 6.3 The modelled flood flows have been informed by a hydrological review of the catchment associated with the UOW (R1) and western ditches within the vicinity of the site. The latest climate change allowances have been incorporated into the hydrological assessment.
- 6.4 The baseline model results provide a representation of surface water sewers within the hydraulic model. By representing the capacity of the sewer network, greater confidence in flooding mechanisms can be taken from the outputs of the hydraulic modelling study than what is otherwise provided by existing datasets (such as the EA surface water mapping). The baseline results show the UOW (R1) to remain in channel for all events adjacent to the site.
- 6.5 Flows are predicted to exceed the capacity of the Severn Trent Water trunk sewers within the residential development south of the site, leading to the manholes surcharging and overland flow being directed to the west of the site. Within the western ditches, R2 is shown to overtop both banks adjacent to the access track on the eastern side of Stoke Road, this is due to a restrictive 600mm diameter culvert. Water also marginally overtops where R4 is assumed to converge with R2, which is associated with a restrictive irregular culvert and a topographical depression adjacent to the road which water pools within.
- 6.6 Sensitivity testing demonstrates that a 20% increase and decrease in Manning's n roughness coefficient leads to increased and decreased peak flood level and floodplain extents respectively.
- 6.7 Additional testing shows the model results are sensitive to changes in downstream boundary in the vicinity of the boundaries. However, further upstream from this, there is no change in peak flood level.

APPENDICES

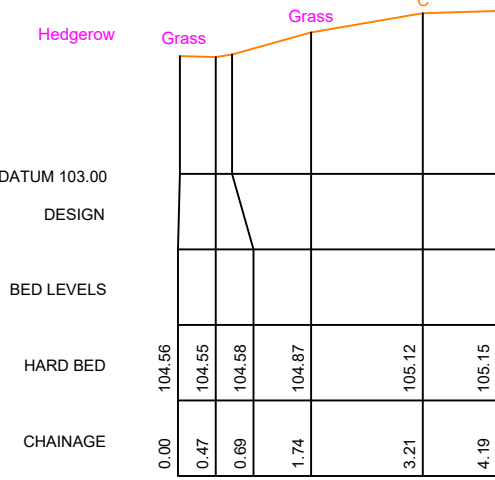
Appendix 1: River Channel Survey



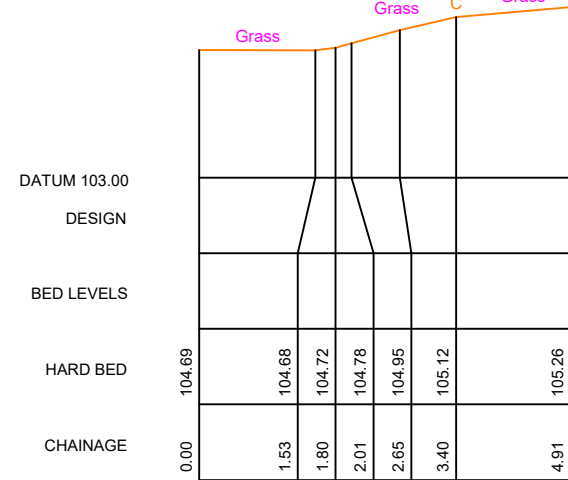
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Open Channel



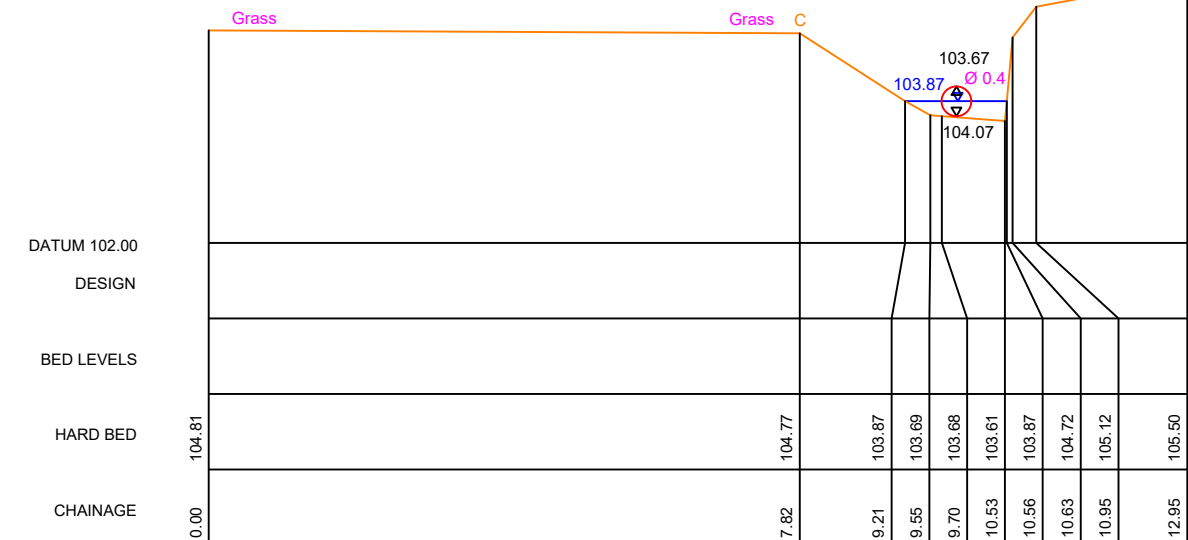
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Open Channel



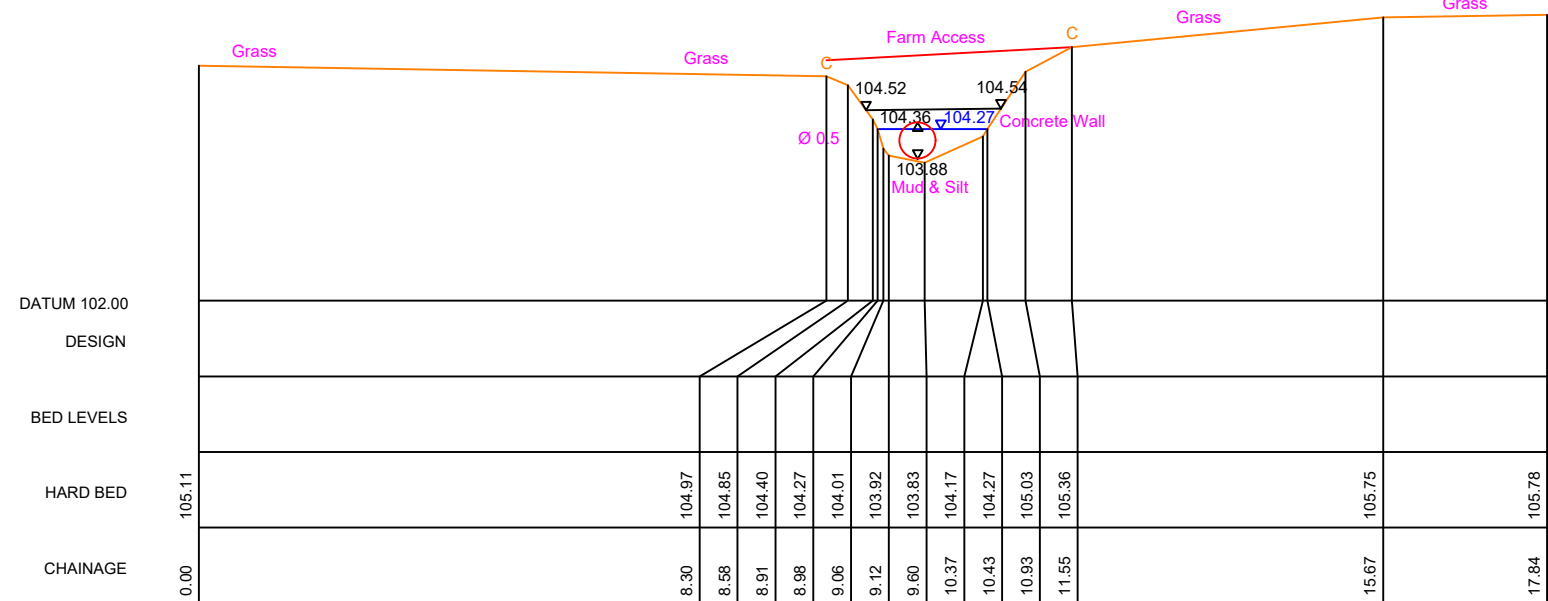
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Open Channel



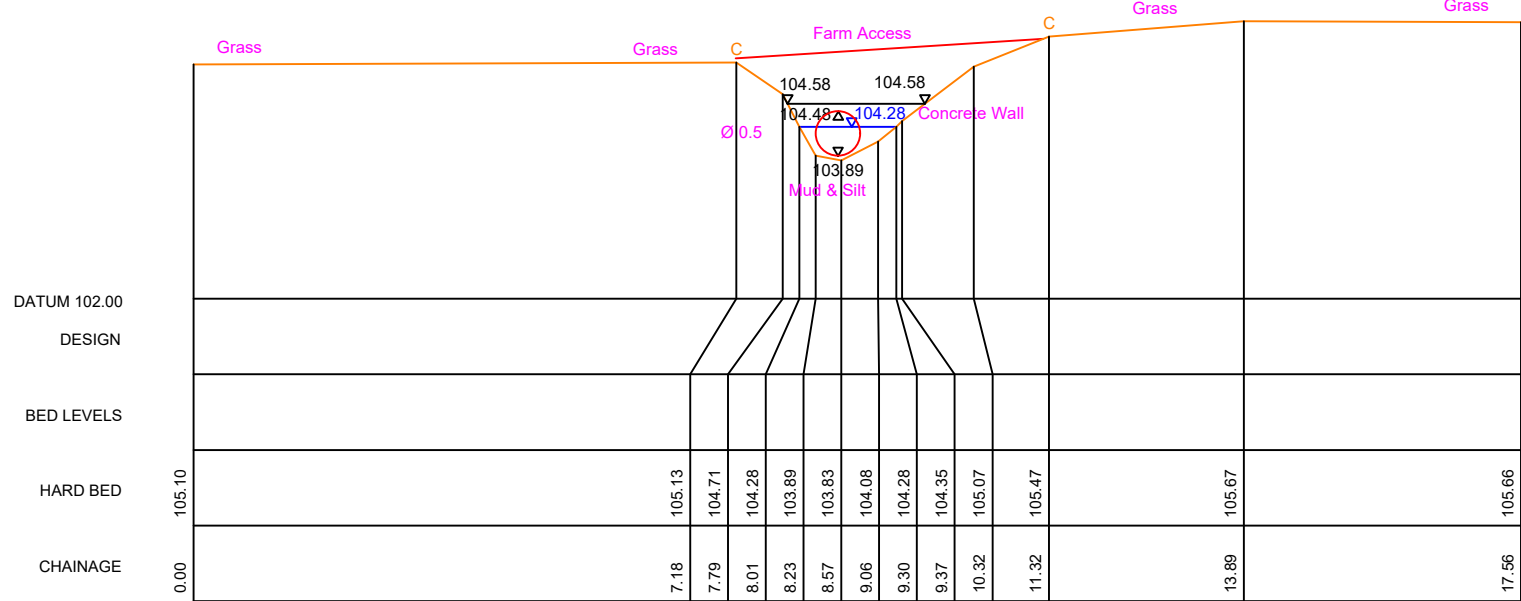
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70.326 M
Open Channel



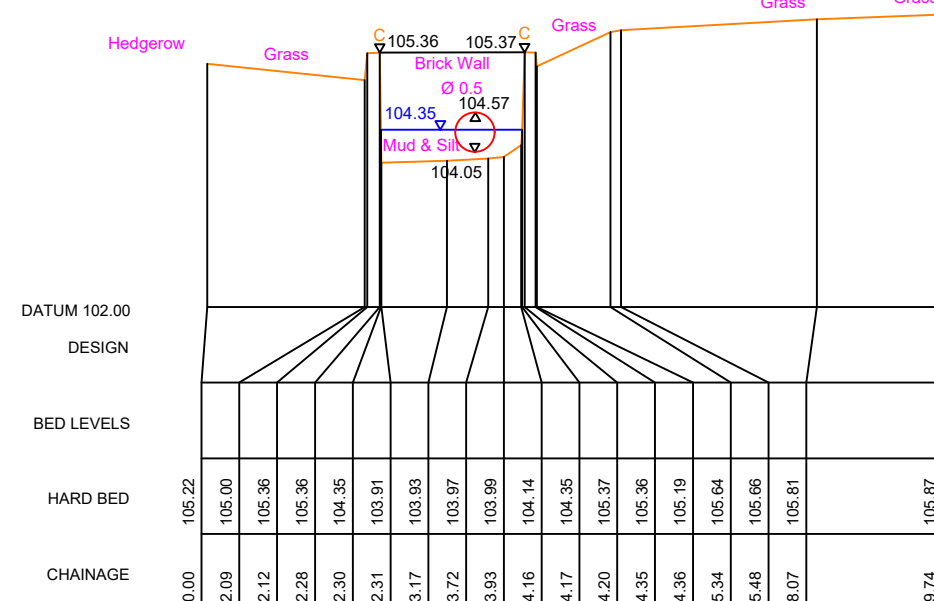
R3_00103
441727.35Em 295548.21Nm BEARING 057Dgr
103.233 M
Culvert



R3_00132
441741.55Em 295523.21Nm BEARING 059Dgr
132.412 M
Culvert



R3_00139
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139.111 M
Culvert

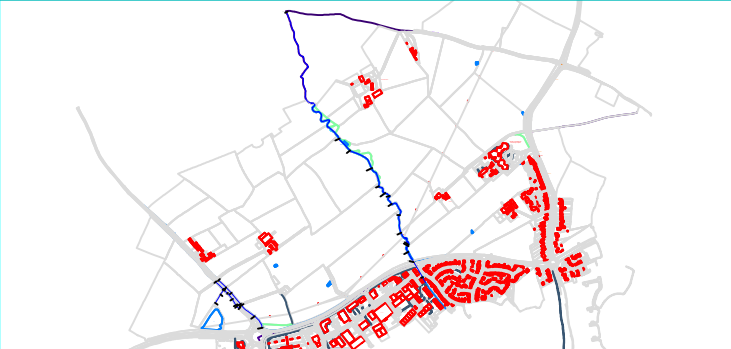


R3_00153
441762.73Em 295511.86Nm BEARING 042Dgr
153.340 M
Culvert

Notes

- Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
- This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
- All dimensions in metres unless noted otherwise. All levels in metres unless noted otherwise.
- Any discrepancies noted on site are to be reported to the engineer immediately.
- No scale factor has been applied to this survey, therefore the co-ordinates are to be treated as arbitrary. Please refer to survey station information below for on site control establishment.
- All coordinates and height data relate to OSGB36(15). Control stations are coordinated by means of GPS receiving real time corrections via OS smart net.
- All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
- OS license number: 100022432

Key Plan



Legend

- OS Buildings
- Surveyed Buildings
- Building
- Wall
- Kerb Channel Line
- Edge of Kerb
- Top of Surface
- Bottom of Bank
- Canopy / Overhang
- Line Marking
- Centre Line
- Watercourse
- Centre Line
- Barrier
- Fence
- Gate
- Overhead Powerline
- Overhead Utilities
- Contour Lines
- Inspection Chamber
- Flow direction and pipe diameter
- Station and Name
- Monitoring Borehole
- Tree / Bush / Sapping
- Area of Vegetation/ Extant of Tree Canopy
- Hedge
- Body of Water
- Body of Water from OS
- Spot Level
- Assumed Surface
- Water Drainage Line
- Surface Water Drainage Line

- AP Anchor Point
- BO Back Gully
- BO Boltard
- BS Bus Stop
- BT British Telecom
- C Crest
- CL Cover Level
- CMP Cable Marker
- Pit
- CCTV/Security Camera
- CIV Cable TV
- DC Drainage
- DK Drain Kerb
- DP Down Pipe
- Elec Electric
- EP Electricity Post
- ER Earth Road
- FH Fire Hydrant
- FL Floodlight
- FBW Fence Barbed Wire
- FOB Fence Closed Board
- FCL Fence Chain Link
- FEL Fence Electric
- FMP Fence Metal Panel
- FMR Fence Metal Rolling
- FOB Fence Open Board
- FPW Fence Post & Wire
- FSP Fence Steel Pipeline
- FWM Fence Wire Mesh
- FYL Finished Floor Level
- FP Flagpole
- Gas
- Gas Valve
- Gully
- Height
- IC Inspection Chamber
- FCL Internal Floor Level
- IL Invert Level
- (as a reduced level)
- LB Litter Bin
- LP Lamp Post
- MH Manhole
- MV Service Marker
- PS Post Box
- PT Post
- RE Roadside Eye
- SP Sign Post
- ST Stop Sign
- SV Stop Valve
- TCB Telephone
- Call Box
- Threshold Level
- TL Traffic Light
- TP Telegraph Post
- TS Traffic Signal
- UTS Unable to Survey
- VL Water Level
- WM Water Meter
- WO Wash Out

P1	09.02.22	First Issue	IR	DS
Rev	Date	Details of issue / revision	Dw	Rev

Issues & Revisions

BWB Birmingham | 0121 233 3322
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London | 020 7407 3879
Manchester | 0161 233 4260
Nottingham | 0115 924 1100
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Client
RICHBOROUGH ESTATES LTD

Project Title
HINCKLEY NORTH

Drawing Title
**WATERCOURSE SURVEY
REACH 3
SHEET 3 OF 6**

Drawn: L.Riley Reviewed: D.Smith

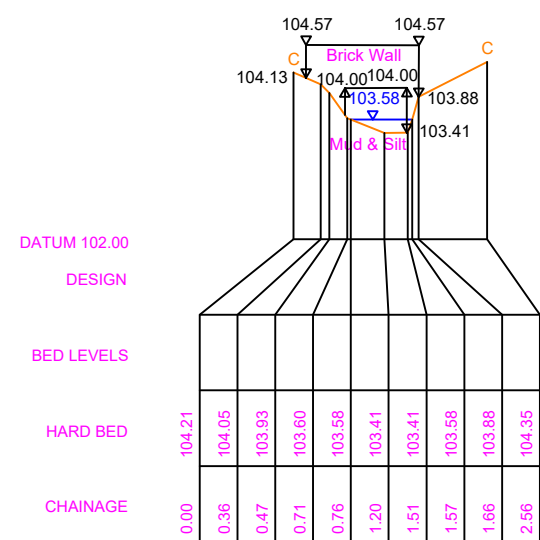
BWB Ref: 210683 Date: 09.02.22 Scale@A0: 1:100

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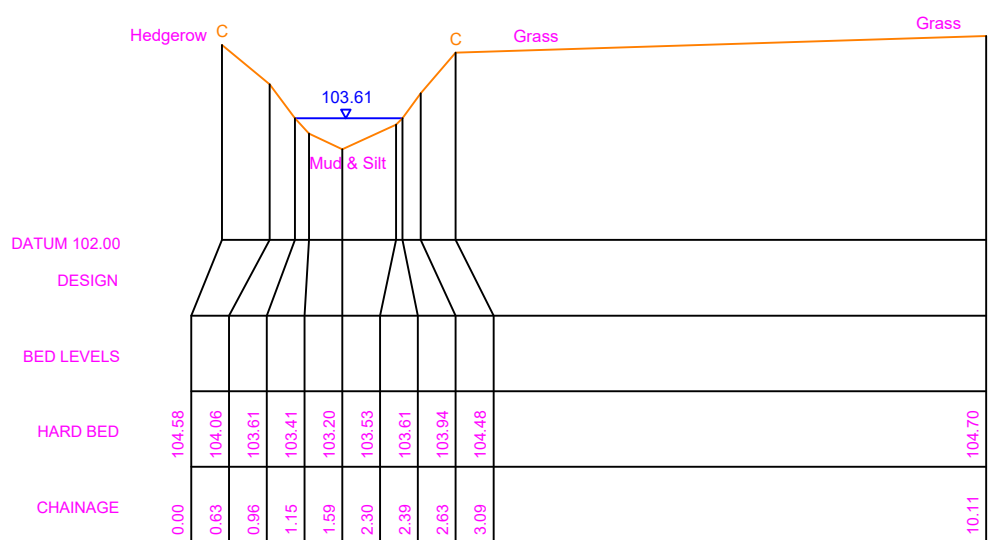
Information

Project - Originator - Zone - Level - Type - Role - Number

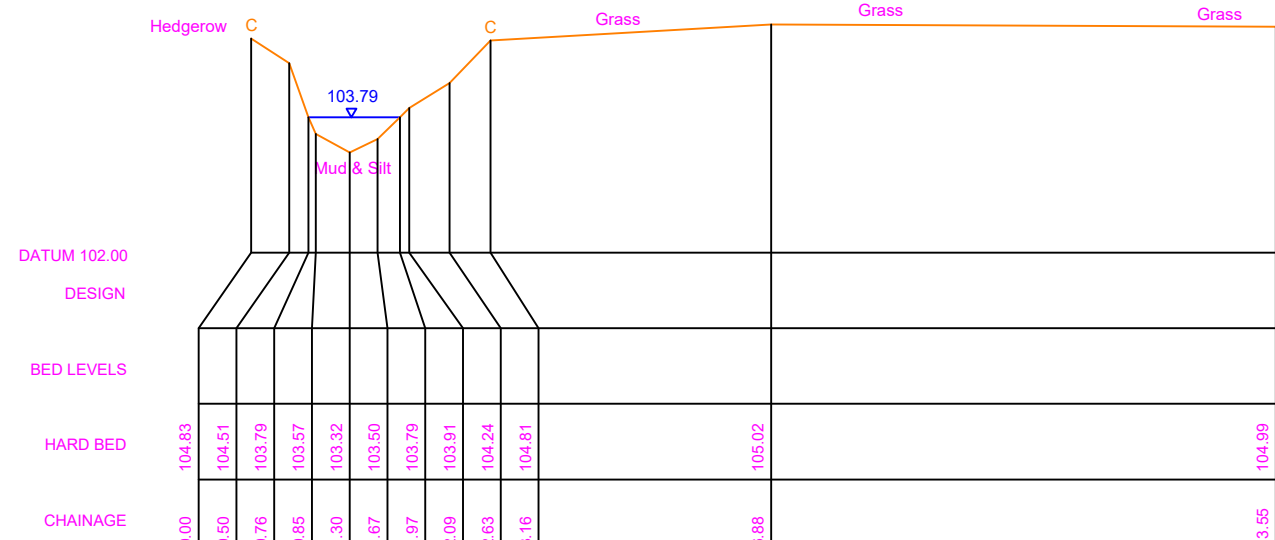
HIN-BWB-03-ZZ-M2-G-0060 **S2** **P1**



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0.173 M
Culvert



R4_00023
441694.77Em 295573.70Nm BEARING 126Dgr
23.358 M
Open Channel

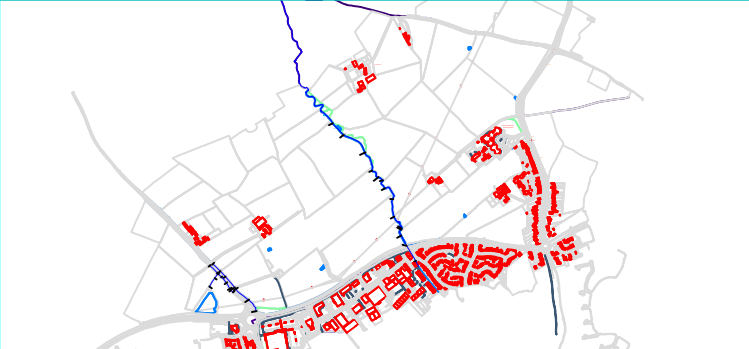


R4_00066
441661.50Em 295538.30Nm BEARING 127Dgr
65.816 M
Open Channel

Notes

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- All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
- OS license number: 100022432

Key Plan



Legend

- OS Buildings
- Surveyed Buildings
- Building
- Wall
- Kerb Channel Line
- Top of Kerb
- Edge of Surface
- Top of Bank
- Bottom of Bank
- Canopy / Overhang
- Line Marking
- Centre Line
- Watercourse
- Centre Line
- Barrier
- Fence
- Gate
- Overhead Powerline
- Overhead Utilities
- Contour Lines
- Inspection Chamber
- Flow direction and pipe diameter
- Station and Name
- Monitoring Borehole
- Tree / Bush / Sapling
- Area of Vegetation/ Extent of Tree Canopy
- Hedge
- Body of Water
- Body of Water from OS
- Spot Level
- Assumed Surface
- Water Drainage Line
- Surface Water Drainage Line

- AP Anchor Point
- BO Back Gully
- BT British Telecom
- CL Cover Level
- CMP Cable Marker
- CCTV Security Camera
- CIV Cable TV
- DC Drainage
- DK Drop Kerb
- DP Down Pipe
- ELC Electric
- EP Electricity Post
- ER Earth Road
- FH Fire Hydrant
- FL Floodlight
- FBW Fence Barbed Wire
- FOB Fence Chain Board
- FCL Fence Chain Link
- FEL Fence Electric
- FMP Fence Metal Panel
- FMB Fence Metal Rolling
- FOB Fence Open Board
- FPW Fence Post & Wire
- FSP Fence Steel Pile/ stake
- FWM Fence Wire Mesh
- FPL Finished Floor Level
- FP Flagpole
- Gas
- OV Gas Valve
- GY Gully
- HS Height
- IC Inspection Chamber
- IFL Internal Floor Level
- IL Invert Level
- (as a reduced level)
- LB Litter Bin
- LP Lamp Post
- MH Manhole
- MV Service Marker
- PS Post Box
- PT Post
- RE Roadside Eye
- SP Sign Post
- SV Stop Valve
- TGB Telephone Call Box
- THL Threshold Level
- TL Traffic Light
- TS Telegraph Post
- TS Traffic Signal
- UTS Unable to Survey
- WL Water Level
- WM Water Meter
- WO Wash Out

P1	09.02.22	First Issue	IR	DS
Rev	Date	Details of issue / revision	Dw	Rev

Issues & Revisions

- Birmingham | 0121 233 3322
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Client

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Project Title

HINCKLEY NORTH

Drawing Title

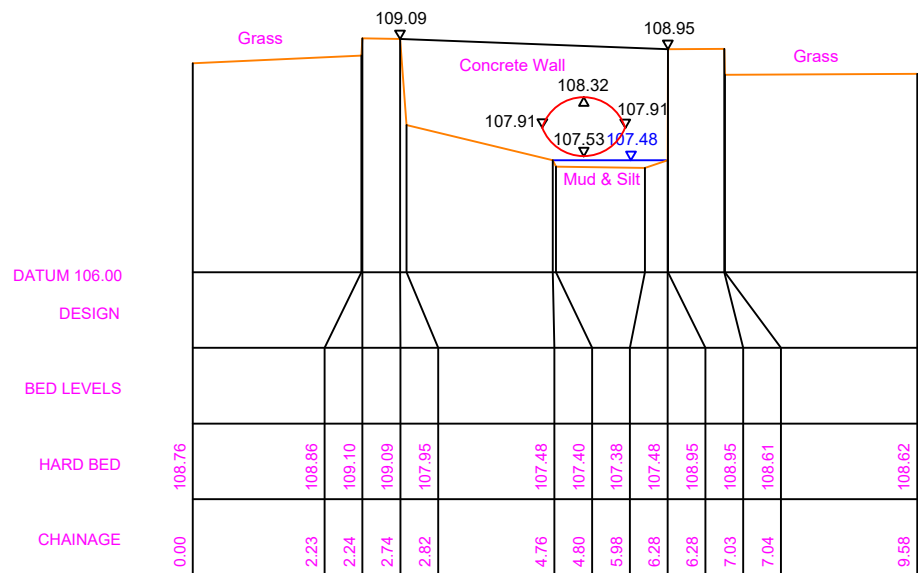
**WATERCOURSE SURVEY
REACH 4
SHEET 4 OF 6**

Drawn:	I.Riley	Reviewed:	D.Smith
BWB Ref:	210683	Date:	09.02.22
Scale@A0:	1:100	Scale@A0:	1:100

Drawing Status

Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
HIN-BWB-04-ZZ-M2-G-0060	S2	P1

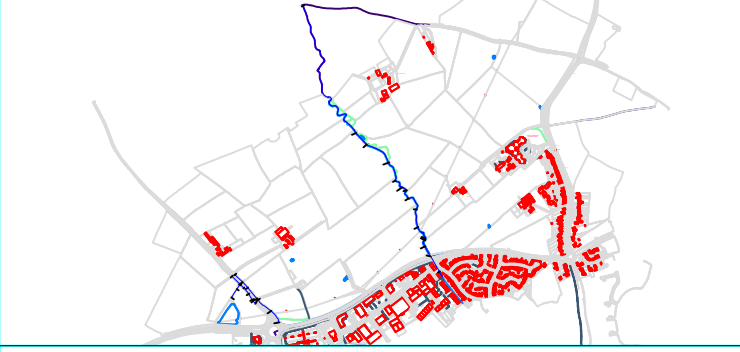


R5 00000
442492.55Em 295730.80Nm BEARING 331Dgr
0.194 M

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7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
8. OS license number: 100022432

Key Plan



Legend

	OS Buildings		Contour Lines
	Surveyed Buildings		Inspection Chamber
	Building		Flow direction and pipe diameter
	Wall		Station and Name
	Kerb Channel Line		Monitoring Borehole
	Top of Kerb		Tree / Bush / Sapling
	Edge of Surface		Area of Vegetation/ Extent of Tree Canopy
	Top of Bank		Hedge
	Bottom of Bank		Body of Water
	Canopy / Overhang		Body of Water from OS
	Line Marking		Spot Level
	Centre Line		Assumed Surface
	Watercourse		Water Drainage Line
	Centre Line		Surface Water Drainage Line
	Barrier		
	Fence		
	Gate		
	Overhead Powerline		
	Overhead Utilities		

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BO	Back Gully	FOB	Fence Chain Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	MV	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PS	Post Box
C	Crest	FMR	Fence Metal Rolling	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker	FPW	Fence Post & Wire	SP	Sign Post
Post	Post	FSP	Fence Steel Pile/ stake	ST	Stop Tap
CCTV/Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve	
CTV	Cable TV	FFL	Finished Floor Level	TGB	Telephone Call Box
DC	Drainage	FP	Flagpole	THL	Threshold Level
DK	Drop Kerb	OV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Ele	Electric	HS	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Road	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level	WM	Water Meter
FL	Floodlight		(as a reduced level)	WO	Wash Out

P1	09.02.22	First Issue	IR	DS
Rev	Date	Details of issue / revision	Dw	Rev

Issues & Revisions

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Project Title

HINCKLEY NORTH

Drawing Title

**WATERCOURSE SURVEY
REACH 5
SHEET 5 OF 6**

Drawn:	I.Riley	Reviewed:	D.Smith
BWB Ref:	210683	Date:	09.02.22
Scale@A0:	1:100		

Drawing Status

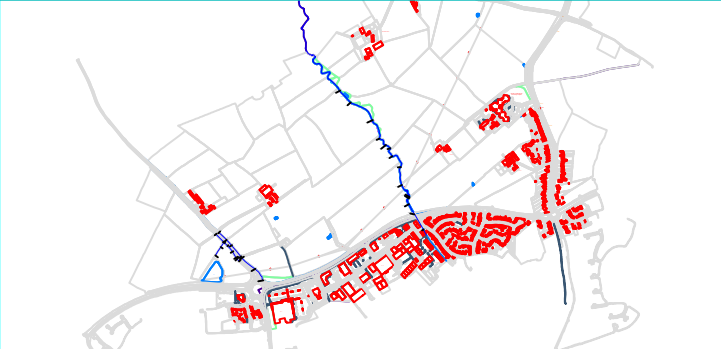
Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
HIN-BWB-05-ZZ-M2-G-0060	S2	P1

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Key Plan



Legend

[illegible]

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Rev	Date	Details of issue / revision	Drw	Rev

Issues & Revisions



Client

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LTD**

Project Title

HINCKLEY NORTH

Drawing Title

**EXISTING WATERCOURSE
LAYOUT
SHEET 6 OF 6**

Drawn:	I.Riley	Reviewed:	D.Smith

Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
HIN-BWB-06-ZZ-M2-G-0060	S2	P1

Appendix 2: Hydrological Assessment

ENVIRONMENT

Richborough Estates Limited and Mr & Mrs
Adcock
Land East of Stoke Road and North of Normandy
Way (A47)
Hinckley
Flow Estimation Record

ENVIRONMENT

Richborough Estates Limited and Mr & Mrs Adcock
Land East of Stoke Road and North of Normandy Way (A47)
Hinckley
Flow Estimation Record

Birmingham
Livery Place, 35 Livery Street, Colmore Business District
Birmingham, B3 2PB
T: 0121 233 3322

Leeds
Whitehall Waterfront, 2 Riverside Way
Leeds, LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street
Manchester, M1 3HU
T: 0161 233 4260

Nottingham
5th Floor, Waterfront House, Station Street
Nottingham, NG2 3DQ
T: 0115 924 1100

March 2022

DOCUMENT ISSUE RECORD

Document Number:	HIN-BWB-ZZ-XX-RP-YE-0001_FER
BWB Reference:	210683-FER

Author:	Lucy Reeves BSc (Hons)
Checked:	Claire Gardner BSc (Hons) MSc MCIWEM C.WEM
Approved:	Max Brambani BSc (Hons) PgCert MCIWEM

Rev	Date	Status	Comment	Author:	Checked:	Approved:
P01	25/03/22	S2	Preliminary Issue	LR	CG	MB

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1. METHOD STATEMENT

Overview of Requirements

- 1.1 Flow estimates are required for input into a hydraulic model of an Unnamed Ordinary Watercourse (UOW) and ditches within the vicinity of the site to quantify the flood risk posed to the development site. The UOW is located to the east of the site and forms a single eastern catchment. The ditches are located to and within the west of the site and form two western catchments. For the purposes of this assessment all features have been given a UOW site code prefix.
- 1.2 The location of the site of interest and the watercourses to be modelled are provided in **Figure 1.1**.

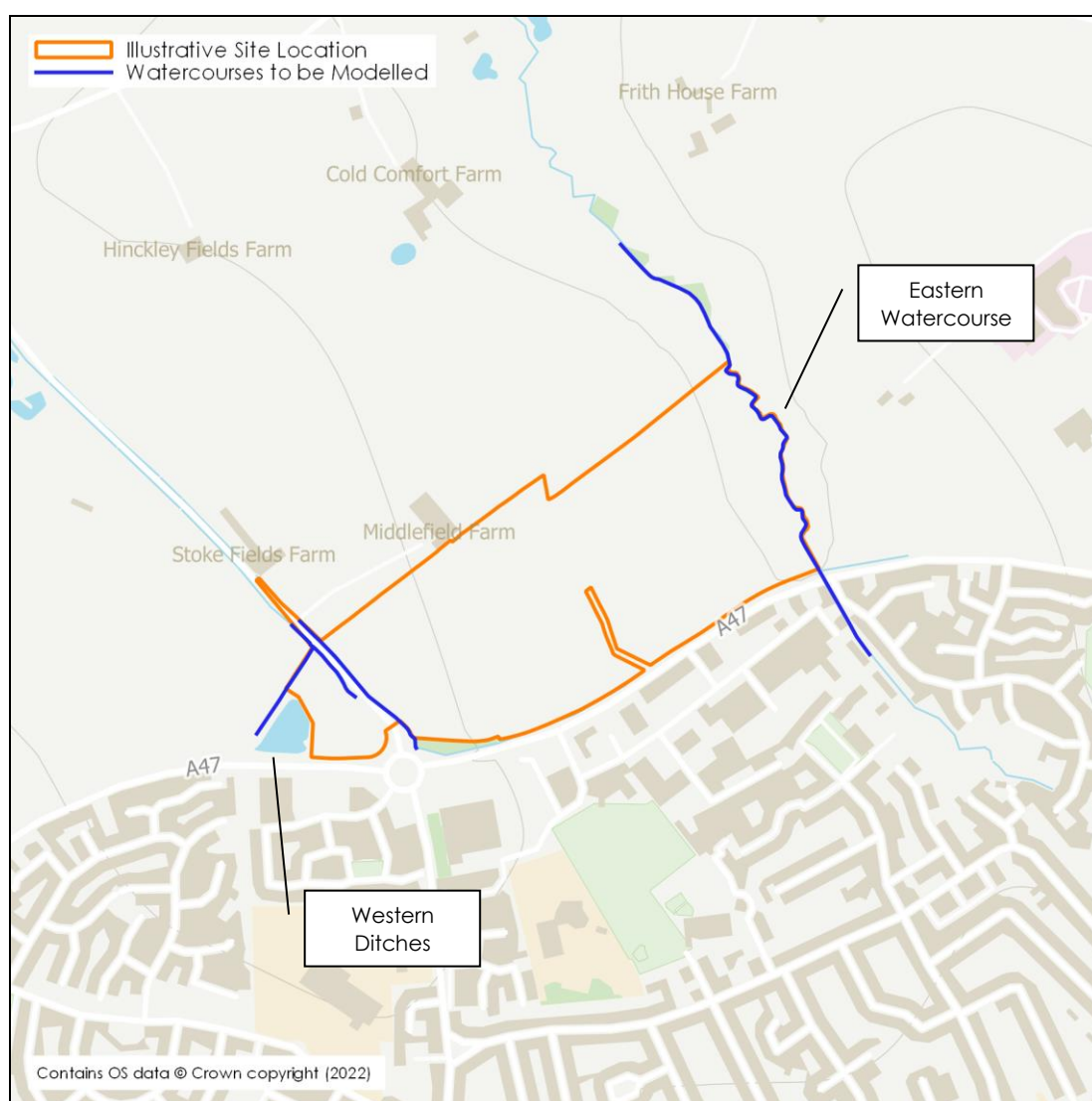


Figure 1.1: Site Location Plan

- 1.3 Return periods to be assessed include: 5, 10, 20, 50, 75, 100, 200 and 1000-years. To inform the design event and potential future floodplain, the 1 in 100-year event with a

range of climate change allowances applied will also be simulated. Hydrographs are required as well as peak flows.

- 1.4 The hydrological assessment was undertaken in February 2022. Version 5 of the Environment Agency (EA) Flood Estimation Guidelines¹ was referred to throughout the hydrological analysis.

Climate Change

- 1.5 Predicted future change in peak river flows caused by climate change are provided by the EA, with a range of projections applied to regionalised 'River Basin Districts', which are further sub-divided into 'Management Catchments'.
- 1.6 The catchments fall within the Tame Anker and Mease Management Catchment of the Humber River Basin District. **Table 1.1** identifies the relevant peak river flow allowances from this Management Catchment.

Table 1.1: Peak River Flow Allowance for the Tame Anker and Mease Management Catchment within the Humber River Basin District

Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2125)
Upper End	24%	30%	51%
Higher Central	15%	17%	30%
Central	10%	11%	22%

- 1.7 When determining the appropriate allowance, the Flood Zone classification, flood risk vulnerability and the anticipated lifespan of a future development should be considered. **Table 1.2** provides a matrix summarising the EA's guidance on determining the appropriate allowances.

Table 1.2: Application of the Appropriate Climate Change Allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
1	Use the central allowance where a location may fall within Flood Zone 2 or 3 in the future.				
2	Use the higher central allowance	Use the central allowance			
3a	Use the higher central allowance	Development should not be permitted	Use the central allowance		

¹ Technical Guidance 197_08 Flood Estimation Guidelines, Environment Agency (June 2020)

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
3b	Use the higher central allowance	Development should not be permitted			Use the central allowance
*If development is considered appropriate when not in accordance with Flood Zone vulnerability categories, then it would be appropriate to use the upper end allowance.					

Available Hydrometric Data

- 1.8 There are no hydrometric gauges within the catchments. Therefore, there are no current hydrometric records of river flows or levels for the watercourse on which a hydrological assessment of flood flows can be made.
- 1.9 The National River Flow Archive (NRFA) Peak Flow Dataset Version 10 (released 27 August 2021) will also be utilised in this assessment for the purposes of identifying any potential donor stations and for the development of pooling groups.

Initial Choice of Approach

Table 1.3: Method Statement

Is FEH appropriate?	Yes. Although the catchments are very small and the upper reaches are heavily urbanised, FEH methods are now the preferred methods for small catchments as well as being suitable for heavily urbanised catchments.
Initial choice of method(s) and reason	Both the FEH Statistical and the ReFH2 methods will be used. Both methods are suitable for the catchments and using both will enable comparison between the two flow estimation methods.
Software to be used	WINFAP v5 and ReFH2 version 2.3

2. LOCATIONS WHERE FLOOD ESTIMATES ARE REQUIRED

Location of Flow Estimates

- 2.1 The eastern watercourse was well-represented within the FEH web service. Therefore, the flow estimation point for this catchment was taken at the downstream extent of the hydraulic model.
- 2.2 The western ditches are not well-represented within the FEH web service. The ditches to be modelled are not shown in the FEH. However, the FEH does show a watercourse starting at a pond just north of the A47. Although this watercourse is misaligned with the ditches to be modelled, it does cover part of the catchments of interest and, therefore, was considered suitable for providing initial catchment descriptors for deriving inflows for the western hydraulic models (catchment descriptors were reviewed and amended accordingly, see **Table 2.2**).
- 2.3 It was decided to calculate flows at the downstream extent of the watercourses only due to the relatively small difference in catchment areas between the upstream and downstream extents of the models.

Table 2.1: Summary of Subject Sites

Site code	Watercourse	Site	Easting	Northing	Area on FEH Webservice	Revised area (if altered)
Eastern Watercourse						
UOW001	Unnamed Ordinary Watercourse	Rogue's Lane	441950	296750	2.3	2.1
Western Ditches						
UOW002	Unnamed Ordinary Watercourse	Farm Track adjacent to Stoke Road	441450	295550	1.0	0.7
UOW003	Unnamed Ordinary Watercourse	Farm Track adjacent to Stoke Road	441450	295550	1.0	0.3

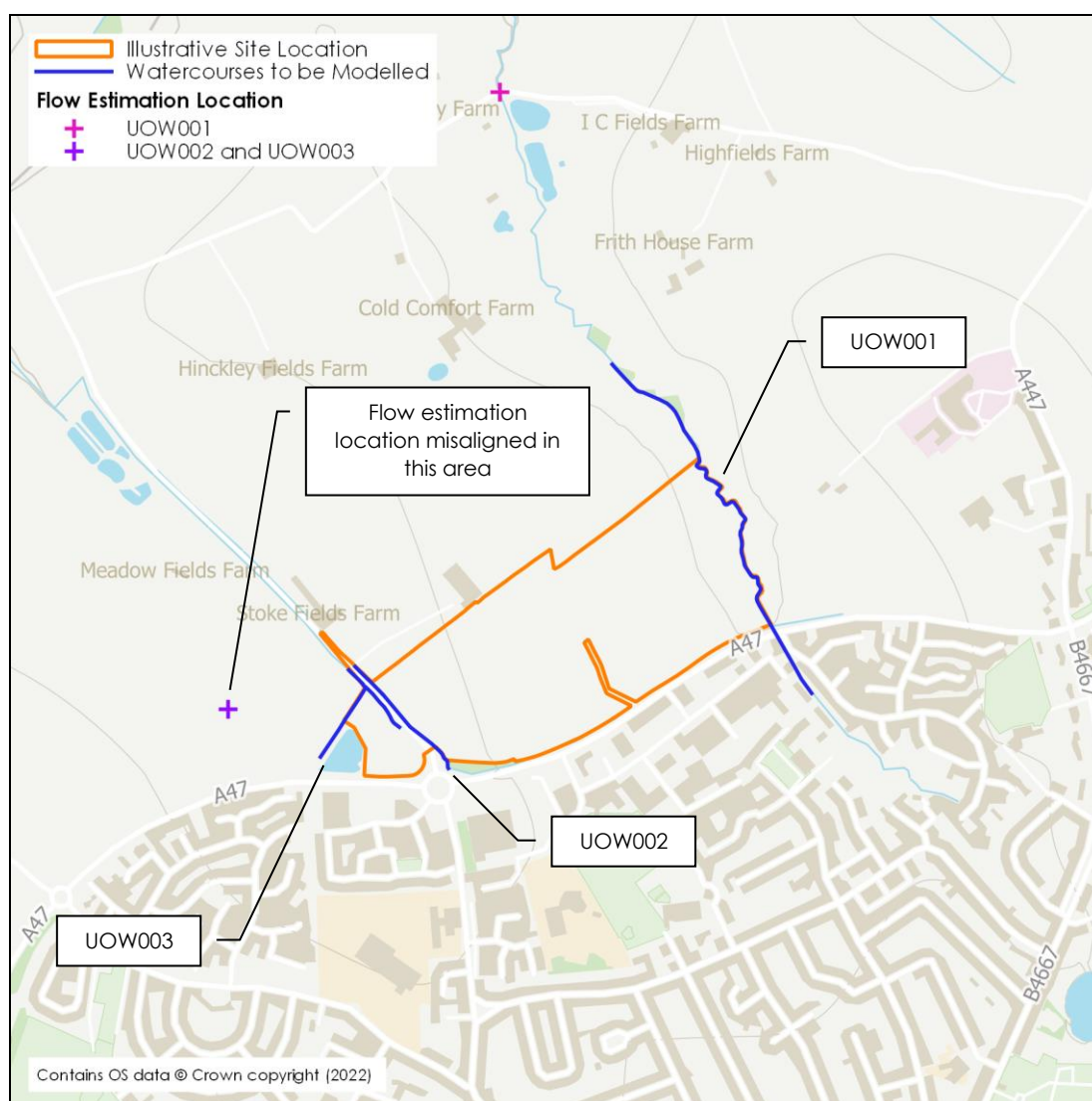


Figure 2.1: Flow Estimation Locations

Checking Catchment Descriptors

Table 2.2: Catchment Descriptor Checks

Record how catchment boundary was checked and describe any changes.	The catchment boundaries for the flow estimation points were identified by the Flood Estimation Handbook (FEH) web service. The boundaries were reviewed and updated using a combination of Ordnance Survey mapping, EA LiDAR and sewer records, where available. Adjustments were required, as demonstrated in Figure 2.2 , Figure 2.3 and Figure 2.4 .
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	The British Geological Survey (BGS) mapping indicates that the watersheds are predominately underlain by the Mercia Mudstone Group. Superficial deposits of Alluvium (Clay, Silt, Sand and Gravel), Bosworth Clay Member (Clay and Silt), Wolston Sand and Gravel and Oadby Member (Diamicton) are also expected to be present throughout the catchments.

	The underlying geology and soils suggest the BFIHOST and SPRHOST values of the FEH catchment descriptors are appropriate for the catchments. The FARL value was checked against OS mapping and was considered representative of the surface water features in the catchments. URBEXT₂₀₀₀ was updated following the changes to the catchment boundaries. DPLBAR has been updated using the standard equation for DPLBAR, given in the FEH Volume 5.
Source of URBEXT	The URBAN50k method has been used to calculate URBEXT₂₀₀₀ for the revised catchment boundaries. FARL was adjusted using the FEH procedure outlined in Volume 5 of the FEH Handbook.
Method for updating of URBEXT to present day.	An update to the current year is not required as the URBAN50k method has been used to calculate URBEXT₂₀₀₀. As such the current urban extent will be implicitly accounted for in the latest mapping.

Table 2.3: Important Catchment Descriptors at Each Subject Site (changes made are highlighted in red)

Site Code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR	SPRHOST	URBEXT 2000 *	FPEXT
Eastern Watercourse									
UOW001	0.951	0.3	0.427	1.52	28	654	44.67	0.2910	0.048
Western Ditches									
UOW002	1	0.3	0.395	0.85	20.3	652	43.8	0.3910	0.1667
UOW003	1	0.3	0.395	0.52	20.3	652	43.8	0.3732	0.1667

* URBEXT₂₀₀₀ updated to 2022

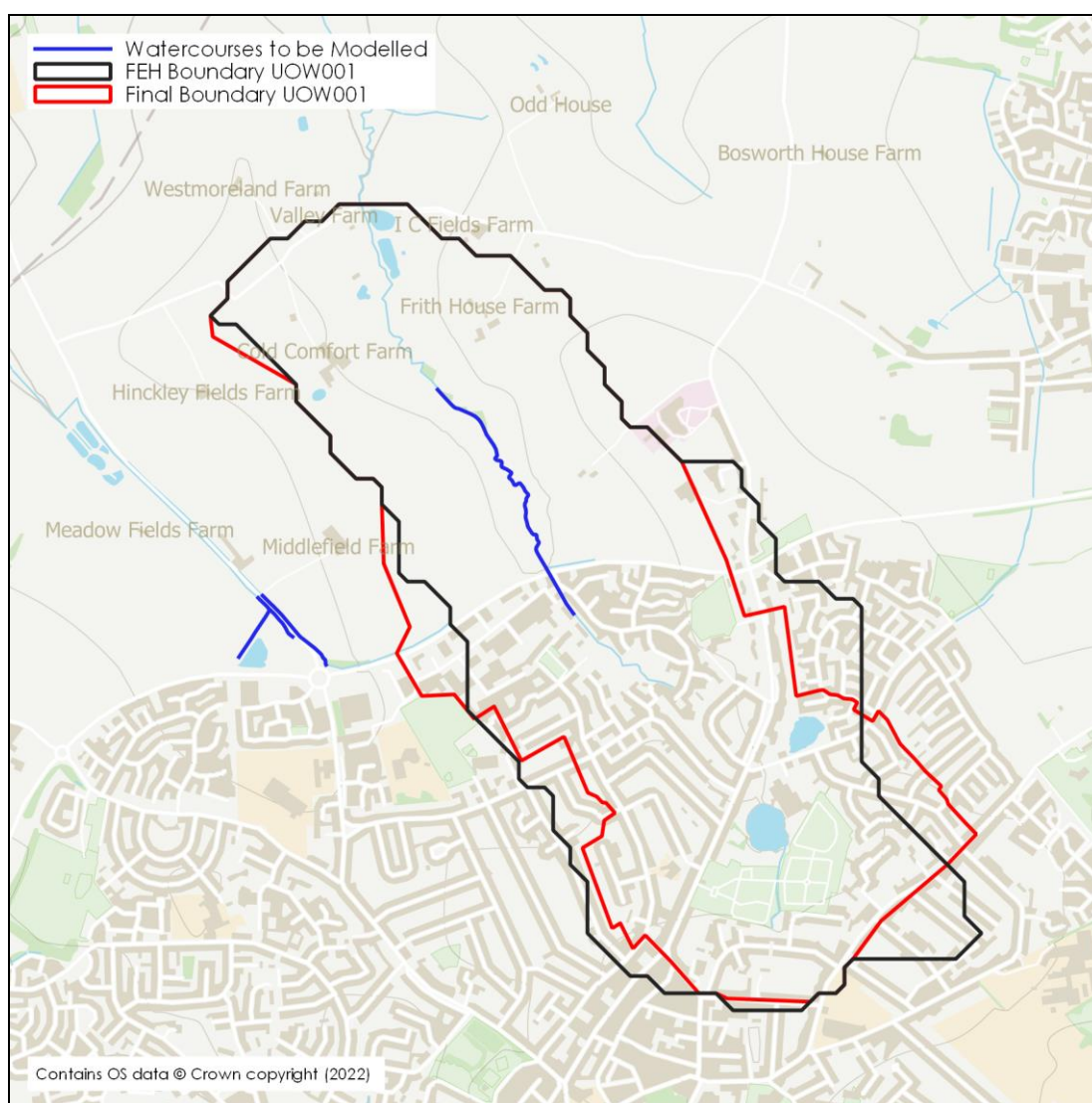


Figure 2.2: Original and Amended Catchment Boundaries – UOW001

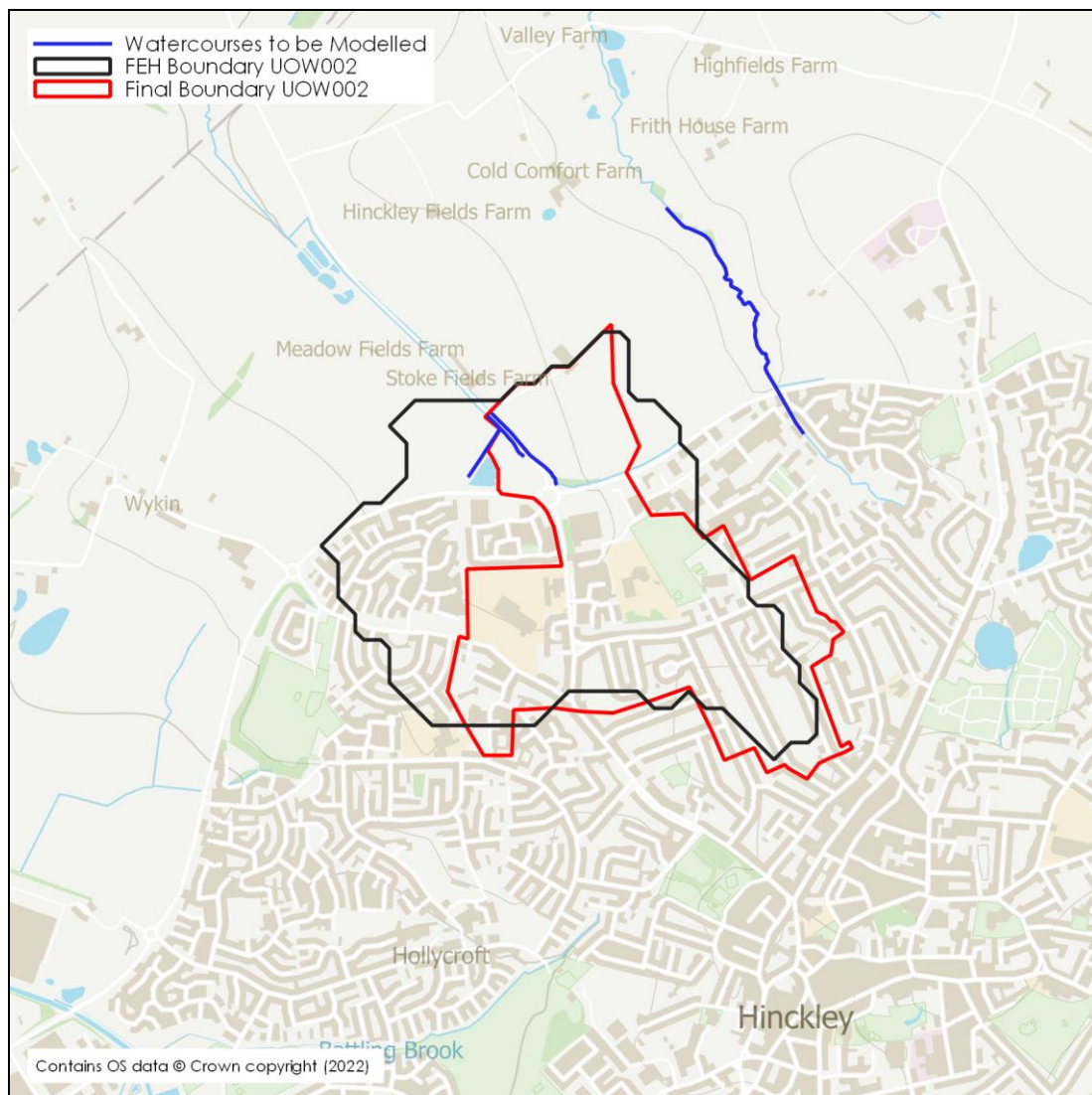


Figure 2.3: Original and Amended Catchment Boundaries – UOW002

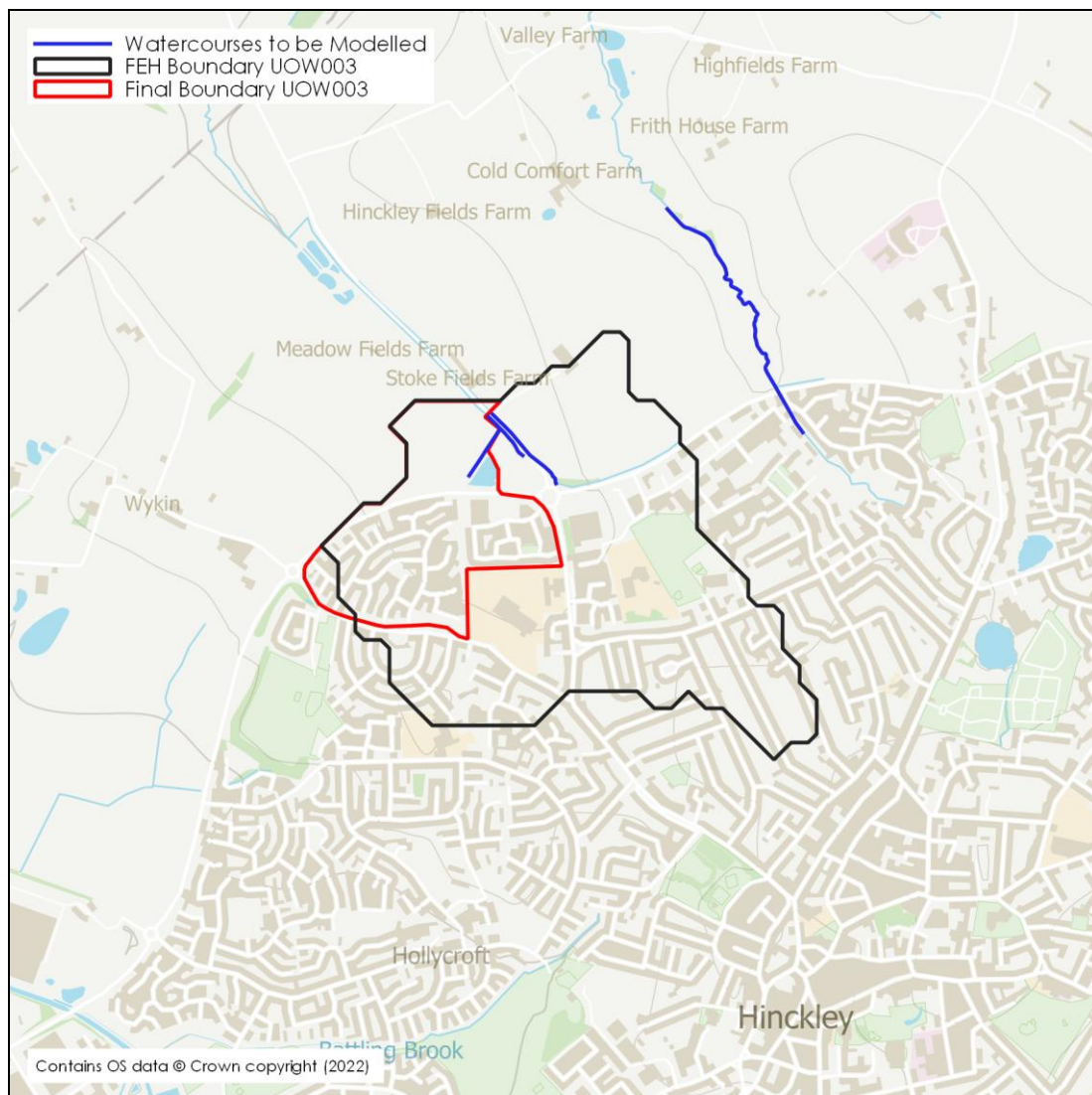


Figure 2.4: Original and Amended Catchment Boundaries – UOW003

3. STATISTICAL METHOD

- 3.1 WINFAP was utilised to undertake a statistical analysis of the catchments using a hydrometric record of gauged catchments with similar characteristics.

QMED Development

- 3.2 Catchment descriptors were originally used to estimate the rural QMED of the study site using the revised equation from Science Report (SC050050). The FEH states that flood frequency is best estimated by gauged data and estimation of key variables from catchment descriptors alone should be a method of last resort. As such, a search was undertaken to identify any potential donor sites that could be used to adjust QMED.
- 3.3 Phase 2 of Science Report SC090031² recommends using a single donor, chosen on the basis of proximity, to adjust QMED for 'small catchments' (defined as catchments with an area of less than 25km²). This method can also be applied to catchments less than 40km².
- 3.4 Whilst the FEH recommends avoiding urbanised donors, the Littlethorpe gauge (NRFA reference: 28082) is approximately 12km from the site and only just over the 0.03 threshold for URBEXT₂₀₀₀. WINFAP allows the use of urban donors, applying the urban adjustment factor in reverse to attempt to remove the urban influence. As such, the search for donors was extended to donors with URBEXT > 0.046 to allow WINFAP to include Littlethorpe as a donor.
- 3.5 With the guidance in mind, a search was undertaken within WINFAP to identify the closest station to the flow estimation point(s). The data quality of potential donor(s) was also reviewed. Of the recommended donors, the following were rejected:
- 28026 – flow bypasses on the left bank, variable drowning due to weed growth and substantial modification owing to Public Water Supply (PWS) imports.
- 3.6 Details for the donor station(s) used to adjust QMED, and which flow estimation point(s) they have been applied to, are provided in **Table 3.1**. Details of the donor adjustment(s) and final QMED estimation are provided in **Table 3.2**.

² Science Report SC090031/R0: Estimating flood peaks and hydrographs for small catchments (Phase 2), Environment Agency (2019).

Table 3.1: Donor Station Details

Station Number	QMED from Observed Data (A)* (m ³ /s)	QMED from Catchment Descriptors (B)** (m ³ /s)	Adjustment Ratio (A/B)	Flow estimation point(s) donor is applied to
28082	15.58	18.593	0.84	UOW001 UOW002 UOW003

* The default, deurbanised observed data was used

** The default, rural, QMED from catchment descriptors was used

Table 3.2: Overview of Estimation of QMED at Each Subject Site

Site Code	Method	Initial Estimate of QMED (M ³ /s) (Rural)	Data Transfer				Final estimate of QMED (URBAN)
			Donor site NRFA no	Distance between centroids d _j (km)	Power term, a	Moderated QMED adjustment factor (A/B) ^a	
Eastern Watercourse							
UOW001	Donor Transfer	0.43	28082	25.71	0.275	1	0.57
Western Ditches							
UOW002	Donor Transfer	0.22	28082	26.11	0.273	1	0.32
UOW003	Donor Transfer	0.10	28082	26.11	0.273	1	0.15
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?				QMED is consistent with the size and characteristics of the catchments.			
Which version of the urban adjustment was used for QMED?				Urban adjustment was applied using Kjeldsen (2010), as applied in WINFAP.			

Derivation of Pooling Groups

- 3.7 A pooled group of hydrologically similar gauged sites was generated by the WINFAP software for the subject sites using the 'OK for Pooling' dataset. WINFAP uses the deurbanised pooling group L-moments as default.
- 3.8 Similarly to QMED estimations, the 'small catchment' method was adopted within WINFAP, in which the pooling group is selected using a similarity measure that only considered AREA and SAAR, as recommended by SC090031.
- 3.9 The catchments for all flow estimation locations were similar in size and characteristics and, therefore, the same pooling group was used.

- 3.10 The pooling group was reviewed to identify sites which may be inappropriate due to being significantly hydrologically dissimilar to the study site, or if they have any inaccuracies, uncertainties, or limitations in their data record.
- 3.11 As the final pooling group contained some permeable catchments (SPRHOST<20%), permeable adjustment was undertaken using WHS Permeable Adjustment Worksheet Beta v1.2.
- 3.12 The growth curve derived from the pooling group was also adjusted to reflect the urban influence using the methods adopted in WINFAP³ which is based on those published by Kjeldsen 20104.
- 3.13 Further detail on pooling group composition is provided in **Section 6**.

Table 3.3: Derivation of Pooling Groups

Name of group	Site code from whose descriptors the group was derived	Subject site treated as gauged? (enhanced single site analysis)	Change made to default pooling group with reasons, including any sites investigated but retaining in the group	Weighted average L-moments L-CV and L-skew (before urban and permeable adjustment)
HIN_PG	UOW001	No	Stations Removed: 7011 – short record (<8 years of data) 44008 – non-flood years account for >15% of the record Stations Added: N/A Comments: The pooling group is heterogeneous and a review of the pooling group is desirable. It is not considered possible to improve the pooling group any further.	L-CV: 0.266 L-Skew: 0.249

³ Wallingford HydroSolutions (2016), WINFAP 4 Urban adjustment procedures, Wallingford HydroSolutions Ltd 2016.

⁴ Kjeldsen, T.K., 2010. Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrology Research, volume 41, issue 5, pp391-405

Table 3.4: Derivation of Flood Growth Curves at Subject Sites

Site code	Method (SS, P, ESS)	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban or permeable adjustment	Growth factor for 1% AEP event
Eastern Watercourse					
UOW001	P	HIN_PG	Generalised logistic provided an acceptable fit and is regarded as the best fit for UK catchments and is the distribution used in the WHS Permeable Adjustment Worksheet Beta v1.2	Urban adjustment using methods adopted in WINFAP which is based on those published by Kjeldsen 2010 Permeable adjustment using WHS Permeable Adjustment Worksheet Beta v1.2	3.12
Western Ditches					
UOW002	P	HIN_PG	Generalised logistic provided an acceptable fit and is regarded as the best fit for UK catchments and is the distribution used in the WHS Permeable Adjustment Worksheet Beta v1.2	Urban adjustment using methods adopted in WINFAP which is based on those published by Kjeldsen 2010	3.06
UOW003	P	HIN_PG	Generalised logistic provided an acceptable fit and is regarded as the best fit for UK catchments and is the distribution used in the WHS Permeable Adjustment Worksheet Beta v1.2	Permeable adjustment using WHS Permeable Adjustment Worksheet Beta v1.2	3.07

Table 3.5: Flood Estimates from the Statistical Method

Site Code	Flood peak (m ³ /s) for the following return periods								
	2	5	10	20	50	75	100	200	1000
Eastern Watercourse									
UOW001	0.6	0.8	1.0	1.2	1.5	1.7	1.8	2.2	3.5
Western Ditches									
UOW002	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.9
UOW003	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.9

4. REVITALISED FLOOD HYDROGRAPH (ReFH) METHOD

- 4.1 The ReFH2 Revitalised Flood Hydrograph Modelling Tool (Version 2.3) was used to undertake an estimation of the peak flows for the subject sites.

Table 4.1: Overview of Parameters for ReFH2 Method

Site code	Method OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer	Tp (hours) Time to peak	C _{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
ALL	Parameters calculated using catchment descriptors.				
Description of flood event analysis carried out			No flood event analysis was possible due to a lack of gauged data for the catchments.		

Table 4.2: ReFH2 Recommended Storm Durations

Site code	Season of design event	Storm duration	Selected interval
Eastern Watercourse			
UOW001	Winter	5.5hrs	0.5hr
Western Ditches			
UOW002	Summer	4.5hrs	0.5hrs
UOW003	Summer	3.25hrs	0.25hrs
Comments	The ReFH2 recommended storm duration and seasons will be taken forward with the modelling and will be used to derive model inflow hydrographs for the watercourse and ditches. As the modelled reach is short, with only a relatively small change in catchment areas between the upstream and downstream model extents, it was not considered necessary to test sensitivity to storm duration.		

Table 4.3: Flood Estimates from the ReFH Method (based on recommended duration for individual catchments)

Site Code	Flood peak (m ³ /s) for the following return periods								
	2	5	10	20	50	75	100	200	1000
Eastern Watercourse									
UOW001	0.6	0.8	1.0	1.2	1.4	1.6	1.7	2.1	3.1
Western Ditches									
UOW002	0.3	0.5	0.6	0.7	0.8	0.9	1.0	1.3	2.0
UOW003	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	1.0

5. DISCUSSION AND SUMMARY OF RESULTS

Comparison of Method

- 5.1 A comparison of the peak flow results for the different estimation methods for the 1 in 2-year and 1 in 100-year events is provided in **Table 5.1**. Comparisons of the growth curves for both methods are shown in **Figure 5.1**, **Figure 5.2** and **Figure 5.3**.

Table 5.1: Comparison of Results

Site code	1 in 2-year peak flows			1 in 100-year peak flows		
	Statistical	ReFH	Ratio	Statistical	ReFH	Ratio
Eastern Watercourse						
UOW001	0.6	0.6	1.0	1.8	1.7	0.9
Western Ditches						
UOW002	0.3	0.3	1.0	1.0	1.0	1.0
UOW003	0.2	0.2	1.0	0.5	0.5	1.0

- 5.2 The Statistical Method provides a steeper growth curve when compared to the ReFH2 Method for UOW001. The Statistical Method provides greater flows for the greater return periods, however for the smaller return periods, flow remain similar.
- 5.3 The Statistical Method and ReFH2 Method provide similar growth curves for UOW002. The ReFH2 Method and Statistical Method provide similar flows.
- 5.4 The ReFH2 Method provides a steeper growth curve when compared to the Statistical Method for UOW001. The ReFH2 Method and Statistical Method provide similar flows.

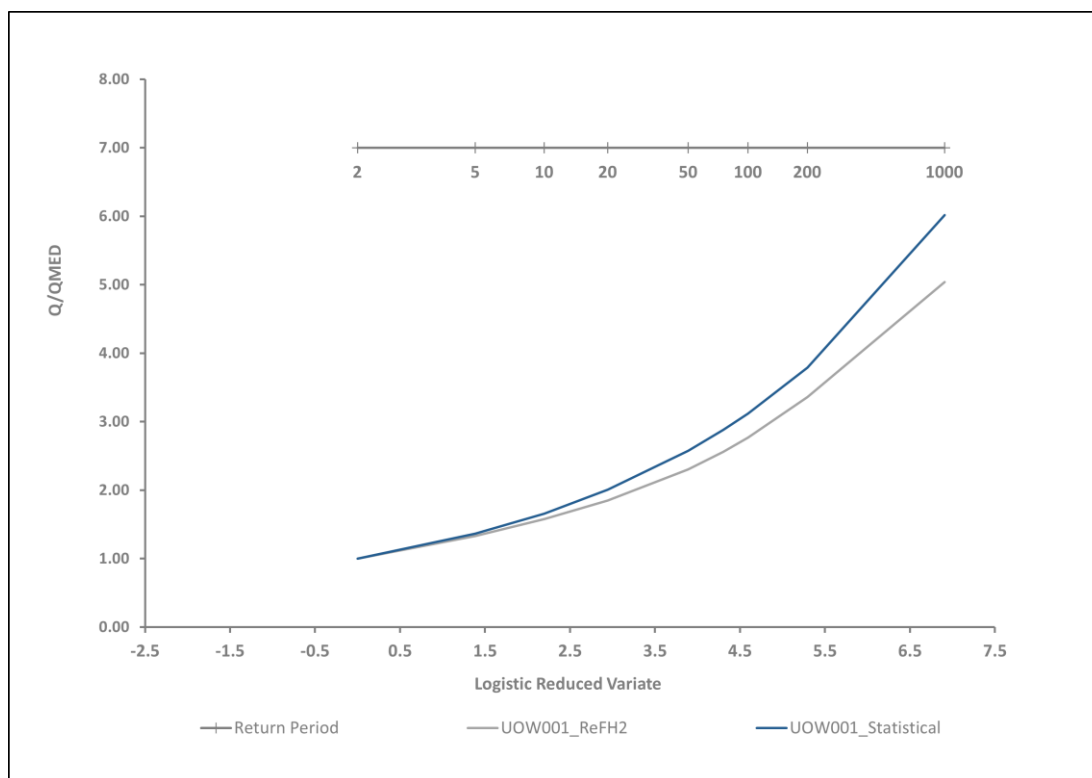


Figure 5.1: Comparison of Statistical Method and ReFH Growth Curves - UOW001

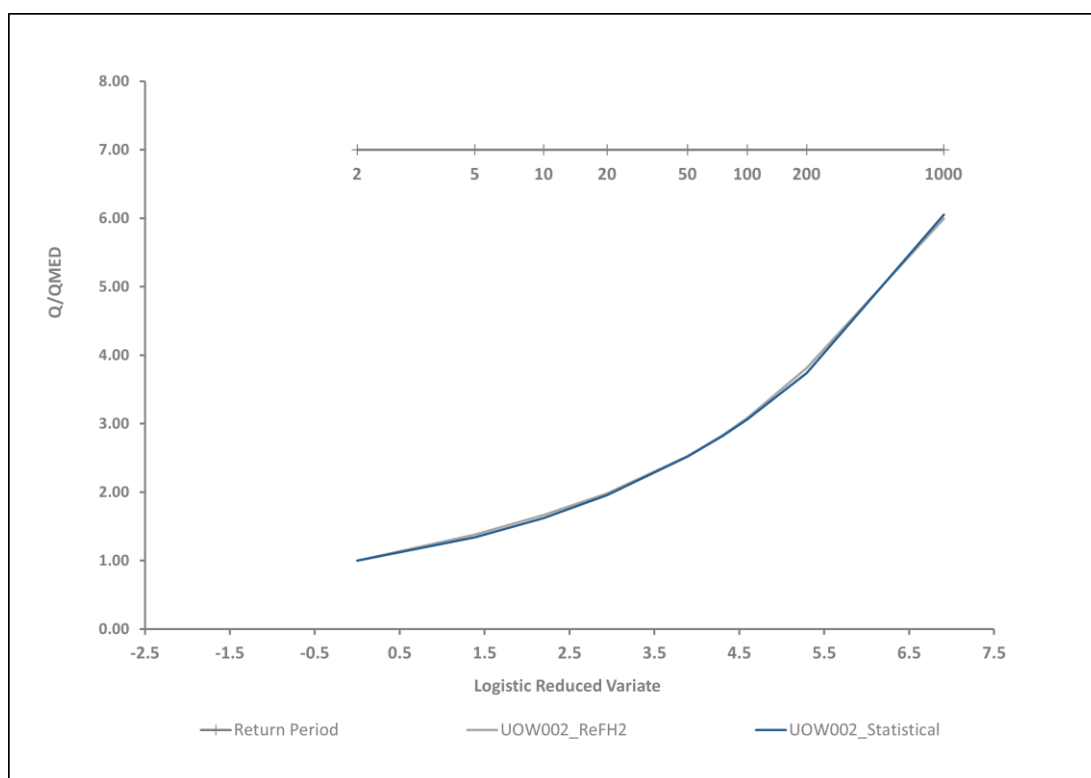


Figure 5.2: Comparison of Statistical Method and ReFH Growth Curves - UOW002

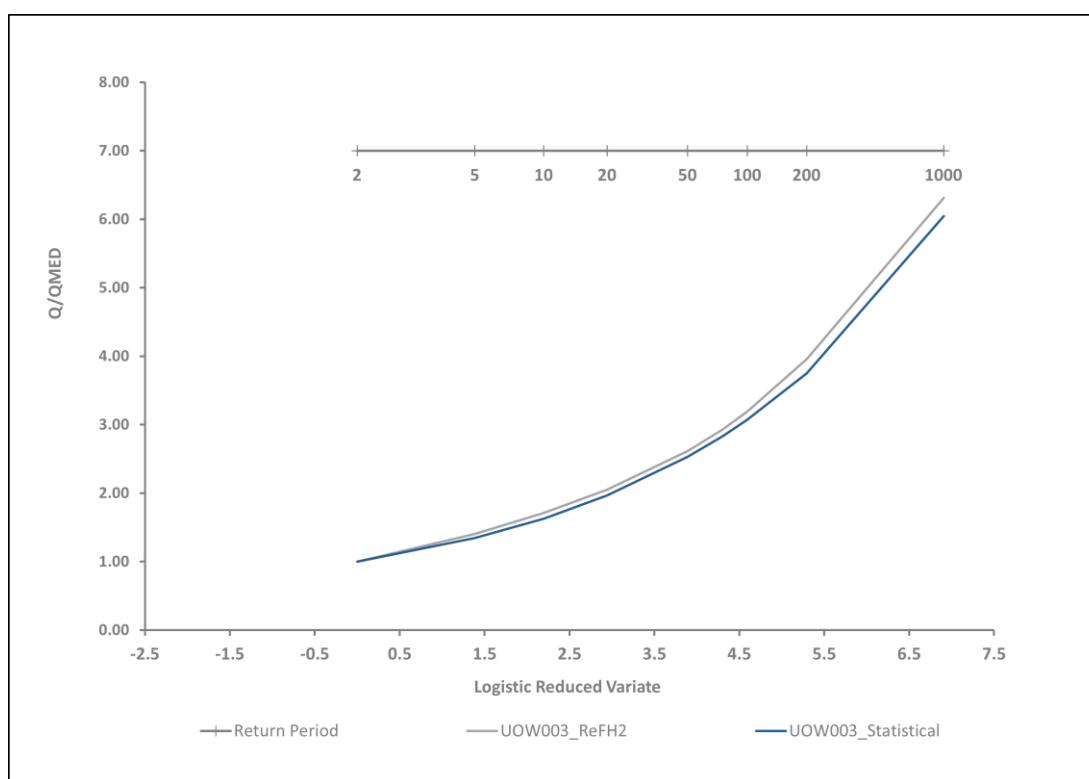


Figure 5.3: Comparison of Statistical Method and ReFH Growth Curves - UOW003

Final Method and Flows

Table 5.2: Final Choice of Method

Choice of method and justification

Whilst both Statistical and ReFH2 methods are considered suitable for UOW001, the final choice of peak flows for input into the model is the Statistical Method, in line with EA FEH Guidelines recommendation. The Statistical Method benefits from an up-to-date flood peak dataset, using growth curves from hydrologically similar catchments to derive a growth curve. The Statistical Method also benefits by avoiding the need to make assumptions about factors such as rainfall duration, time of concentration and the nature of the design flood, unlike the ReFH2 Method.

ReFH2 will be used to provide a hydrograph shape for the UOW001 model inflows, scaled to the Statistical peak.

Whilst both Statistical and ReFH2 methods are considered suitable for UOW001, the final choice of peak flows for input into the model is the ReFH2 Method. Whilst the Statistical method is generally the preferred method set out in the EA Guidelines, for the ditches, the flow estimates being calculated for are not real topographic catchments, with their upper reaches defined by sewer catchments. As such, the FEH Statistical method is not strictly applicable and ReFH 2 was preferred due to the influence of sewers at the upstream extent of the ditches.

Table 5.3: Final Peak Flows for the Eastern Watercourse from Chosen Method (Statistical)

Site Code	Flood peak (m ³ /s) for the following return periods								
	2	5	10	20	50	75	100	200	1000
UOW001	0.6	0.8	1.0	1.2	1.5	1.7	1.8	2.2	3.5

Table 5.4: Final Peak Flows for the Western Ditches from Chosen Method (ReFH)

Site Code	Flood peak (m ³ /s) for the following return periods								
	2	5	10	20	50	75	100	200	1000
UOW002	0.3	0.5	0.6	0.7	0.8	0.9	1.0	1.3	2.0
UOW003	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	1.0

Table 5.5: Assumptions, Limitations and Uncertainty

List the main assumptions made	- The pooling groups are representative of the catchments. - The ReFH2 hydrograph shape is representative of the catchment responses. - Tp and storm duration is representative of the catchment responses. - The flow estimate derived at the downstream extent of the watercourses is applicable to the upstream catchments. - It is assumed that the misaligned FEH catchment is representative of the catchments associated with the western ditches. - It is assumed that FEH methods are suitable for the western ditches, although they are not strictly 'real' catchments.
Discuss any limitations e.g. applying methods outside the range of catchment types or return periods for which they were developed	- The FEH Statistical and ReFH2 methods are believed to be suitable up to the 1 in 200-year event. Estimates of flow beyond these events are extrapolations and, therefore, have a higher level of uncertainty. - There are only a small number of gauged sites in the UK. As such the representation in the pooling is not ideal given the small size of some of the study catchments. - There is no observed flow data within the catchments with which to verify the flow estimates.
Give what information you can on uncertainty in the results	Section 5.4 sets out confidence intervals for the Statistical method at ungauged sites. However, confidence intervals for heavily urbanised sites are not provided because there are not enough suitable catchments with flood peak data to provide reliable results.

	Donor transfer has been undertaken using data from a nearby gauge. Use of a donor station is considered to provide more reliable estimates compared to those calculated from catchment descriptors alone. It is more difficult to quantify uncertainty in design flows estimated from the ReFH rainfall-runoff model. However, evidence⁵ suggests the factorial standard errors from ReFH2 are comparable to those observed for the FEH pooled Statistical method when the catchment is treated as ungauged.
Comment on the suitability of the results for future studies	The design flow estimates have been derived for the purpose of providing flow hydrographs into a hydraulic model to support an understanding of flood risk at the development site. Users for different studies should, as a minimum, review results to assess suitability for the purpose of the study.
Give any other comments on the study	While the installation of temporary flow gauges would provide local data with which to better inform the design peak flows, this would not align with the timescales of this project.

Table 5.6: Checks

Are the results consistent?	Peak flows are consistent with the size and characteristics of the catchments.
What do the results imply regarding the return periods of floods during the period of record?	A flood history review for the area has been undertaken (Section 6). The Level 1 SFRA notes that a surface water overland flow route exists along Stoke Road and is associated with an unnamed drain adjacent to this road; however there are no historical flooding incidents recorded. There is no detailed information available for this event and no hydrometric data available for the catchments.
What is the 1 in 100-year growth factor? (the guidance suggests a typical range or 2.1 to 4.0)	- The 1 in 100-year growth factor for the Statistical Method is 3.12 for UOW001, 3.06 for UOW002 and 3.07 for UOW003. - The 1 in 100-year growth factor for the ReFH2 Method is 2.77 for UOW001, 3.08 for UOW002 and 3.19 for UOW003. These fall within the typical range.
If 1 in 1000-year flows have been derived, what is the range of ratios for 1 in 1000-year flow over 1 in 100-year flow?	- Statistical Method: ratio for UOW001 is 1.93, for UOW002 is 1.98 and for UOW003 is 1.97. - ReFH2 Method: ratio for UOW001 is 1.82, for UOW002 is 1.94 and for UOW003 is 1.98.

⁵ Wallingford Hydrosolutions (2019) ReFH2 Science Report: Evaluation of the Rural Design Event Model.

How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred	There are no previous studies with which to compare results.
Are the results consistent with the longer-term flood history?	A flood history review has been undertaken and the Level 1 SFRA notes that a surface water overland flow route exists along Stoke Road and is associated with an unnamed drain adjacent to this road, however there are no historic flooding incidents recorded. It is unknown whether this surface water flow route affects the development site. No specific details on the flows are recorded and there is no hydrometric data within the catchments with which to compare.
Describe any other checks on the results	Sensibility checks of modelled outlines will be undertaken at the modelling stage.

Application of Flows to Model

5.5 Flows will be applied to the model in the following way.

UOW001

- i. To derive hydrographs for UOW001, the ReFH2 hydrographs were scaled to meet the Statistical Method peak flows.
- ii. The model extent was located further upstream than the flow estimation location and, therefore, the flows were pro-rated to cover a catchment that would drain to the extent of the watercourse modelled.
- iii. Normandy Way, located to the south of the site, represents a catchment division. Therefore, the inflows have been prorated between the upstream and downstream catchment of Normandy Way.
- iv. Two surface water sewers are understood to outfall to the UOW adjacent to Normandy Way; therefore an inflow was applied to each of the sewers at the head of the run. The inflows were prorated between each of the sewers and the UOW.

5.6 **Figure 5.4** demonstrates how the flows will be applied to the model for UOW001.

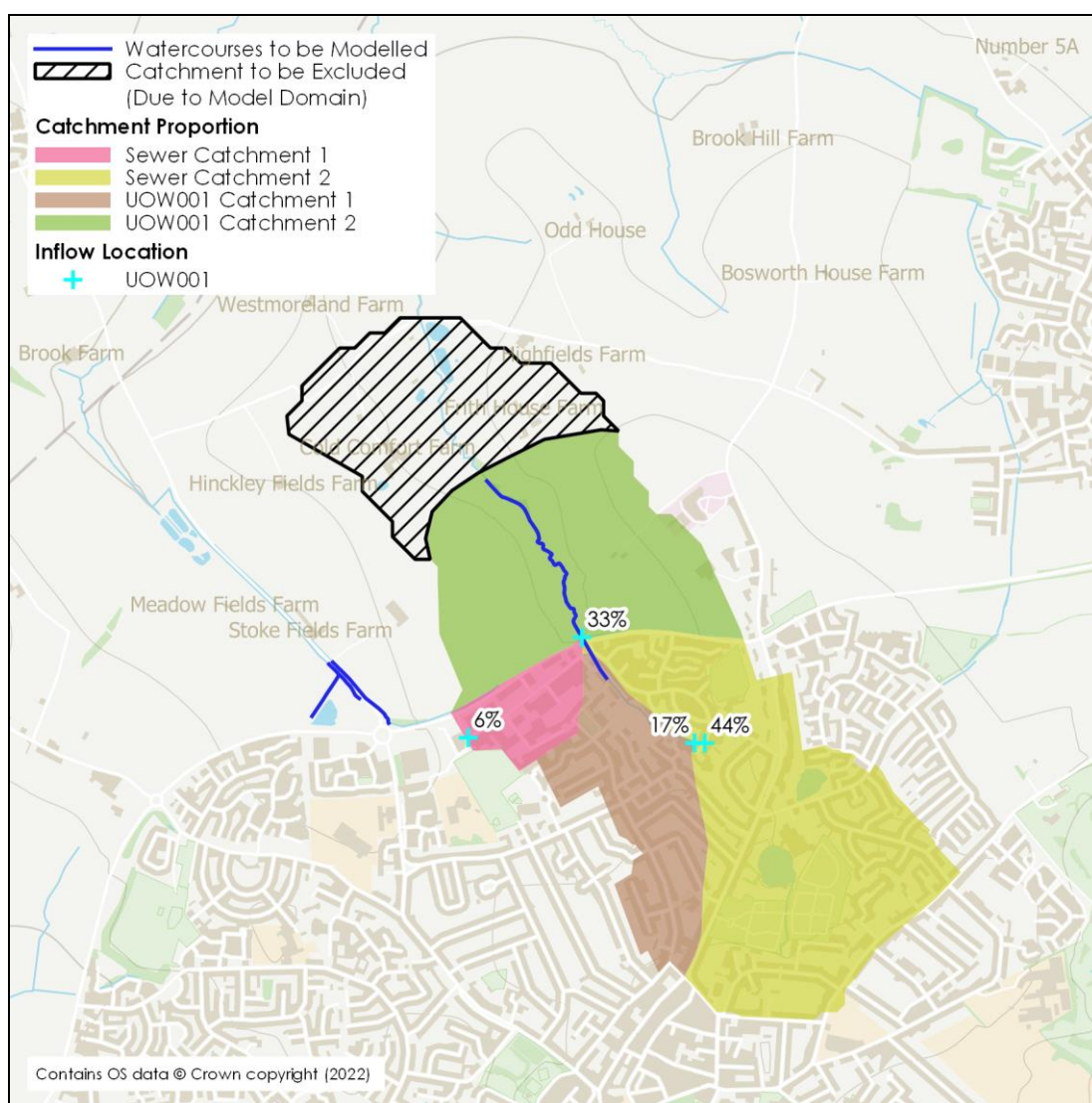


Figure 5.4: Application of Inflows into Model – UOW001

UOW002

- ReFH2 hydrographs were used and applied to the model.
- Normandy Way, located to the south of the site, represents a catchment division. Therefore, the inflows have been prorated between the upstream and downstream catchment of Normandy Way.
- Two surface water sewers are understood to outfall to the UOW adjacent to Normandy Way, therefore an inflow was applied to each of the sewers at the head of the run. The inflows were prorated between each of the sewers and the UOW.

5.7 **Figure 5.5** demonstrates how the flows will be applied to the model for UOW002.

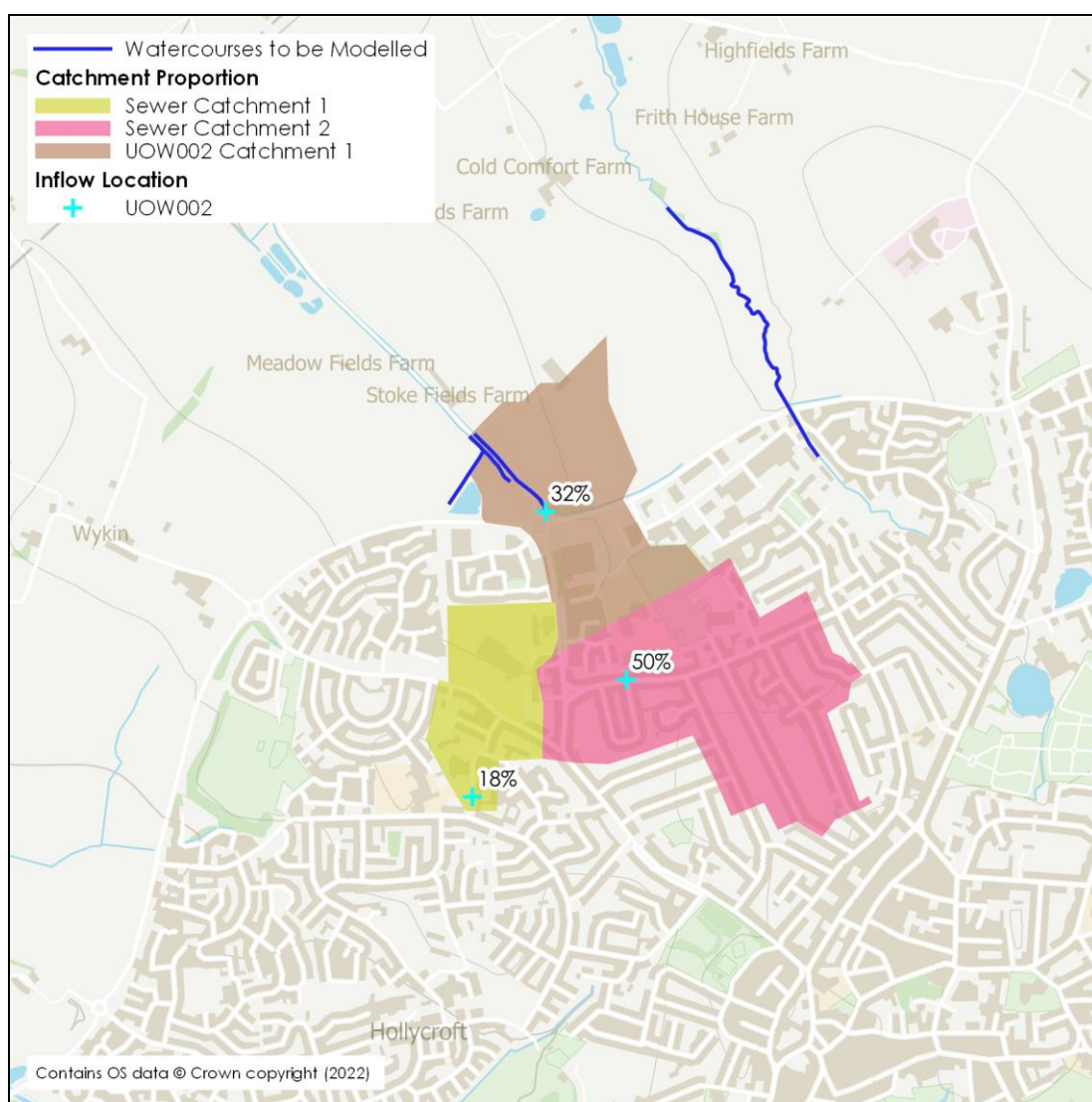


Figure 5.5: Application of Inflows into Model – UOW002

UOW003

- i. ReFH2 hydrographs were used and applied to the model.
- ii. Normandy Way, located to the south of the site, represents a catchment division. Therefore, the inflows have been prorated between the upstream and downstream catchment of Normandy Way.
- iii. One surface water sewer is understood to outfall to the UOW adjacent to Normandy Way, therefore an inflow was applied to the sewers at the head of the run. The inflows were prorated between each of the sewers and the UOW.

5.8 **Figure 5.6** demonstrates how the flows will be applied to the model for UOW003.

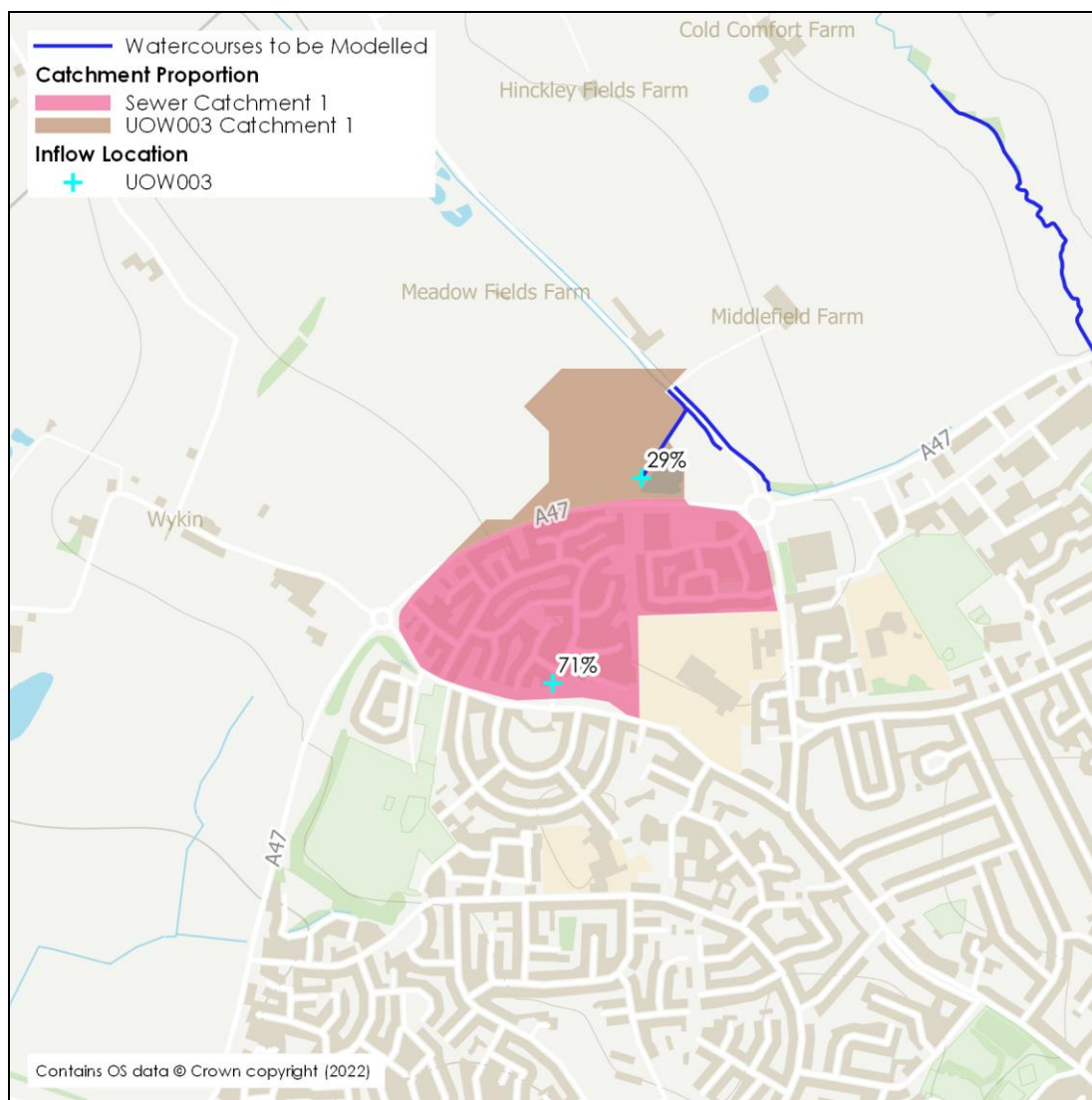


Figure 5.6: Application of Inflows into Model – UOW003

6. SUPPORTING INFORMATION

Flood History

- 6.1 A flood history review for the catchments has been undertaken using EA recorded flood outlines, Hinckley and Bosworth Borough Council Level 1 Strategic Flood Risk Assessment (SFRA)⁶, Hinckley and Bosworth Borough Council Level 2 SFRA⁷, Leicestershire County Council Preliminary Flood Risk Assessment (PFRA)⁸, Leicestershire County Council Local Flood Risk Management Strategy (LFRMS)⁹, the British Chronology of Hydrological Events and online newspaper records.
- 6.2 The Level 1 SFRA notes that a surface water overland flow route exists along Stoke Road and is associated with an unnamed drain adjacent to this road, however there are no historic flooding incidents recorded. It is unknown whether this surface water flow route affects the development site.

Detailed Pooling Group Information

- 6.3 The default pooling group generated by WINFAP is provided in **Table 6.1** and the final pooling group following review is provided in **Table 6.2**. Permeable adjusted L-CV and L-Skew are provided in **Table 6.3**.

Table 6.1: Default Pooling Group: HIN_PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
27073 (Brompton Beck @ Snainton Ings)	1.086	40	0.816	0.215	0.019	1.186
27051 (Crimple @ Burn Bridge)	1.309	48	4.544	0.22	0.145	0.367
76011 (Coal Burn @ Coalburn)	1.495	43	1.84	0.167	0.303	1.112
26016 (Gypsey Race @ Kirby Grindalythe)	1.639	23	0.101	0.312	0.258	0.149
25019 (Leven @ Easby)	1.689	42	5.384	0.339	0.385	0.231
45816 (Haddeo @ Upton)	1.986	27	3.456	0.299	0.416	0.747
36010 (Bumpstead Brook @ Broad Green)	2.045	53	7.5	0.379	0.172	1.654
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	2.084	10	5.972	0.257	0.135	2.898
27010 (Hodge Beck @ Bransdale Weir)	2.085	41	9.42	0.224	0.293	0.356
26014 (Water Forlornes @ Driffield)	2.168	22	0.431	0.299	0.119	0.656
44008 (South Winterbourne @ Winterbourne Steepleton)	2.172	41	0.448	0.408	0.318	0.572

⁶ Level 1 Strategic Flood Risk Assessment (JBA Consulting, July 2019)

⁷ Level 2 Strategic Flood Risk Assessment (JBA Consulting, May 2020)

⁸ Preliminary Flood Risk Assessment (Leicestershire County Council, June 2011)

⁹ Local Flood Risk Management Strategy (Leicestershire County Council, August 2015)

28033 (Dove @ Hollinsclough)	2.313	45	4.15	0.225	0.373	0.864
7011 (Black Burn @ Pluscarden Abbey)	2.322	7	5.205	0.544	0.571	2.59
41020 (Bevern Stream @ Clappers Bridge)	2.386	51	13.66	0.205	0.171	0.725
39033 (Winterbourne Stream @ Bagnor)	2.43	58	0.401	0.342	0.382	0.893
Total		551				
Weighted Means				0.288	0.263	
H2 value	2.6958					
Goodness of Fit	Generalised Logistic			General Extreme Value		
	0.1471			-1.1661		

Table 6.2: Final Pooling Group (before permeable adjustment): HIN_PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
27073 (Brompton Beck @ Snainton Ings)	1.086	40	0.816	0.215	0.019	1.383
27051 (Crimple @ Burn Bridge)	1.309	48	4.544	0.22	0.145	0.363
76011 (Coal Burn @ Coalburn)	1.495	43	1.84	0.167	0.303	1.187
26016 (Gypsey Race @ Kirby Grindalythe)	1.639	23	0.101	0.312	0.258	0.22
25019 (Leven @ Easby)	1.689	42	5.384	0.339	0.385	0.799
45816 (Haddeo @ Upton)	1.986	27	3.456	0.299	0.416	1.048
36010 (Bumpstead Brook @ Broad Green)	2.045	53	7.5	0.379	0.172	1.761
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	2.084	10	5.972	0.257	0.135	2.629
27010 (Hodge Beck @ Bransdale Weir)	2.085	41	9.42	0.224	0.293	0.277
26014 (Water Forlornes @ Driffield)	2.168	22	0.431	0.299	0.119	0.629
28033 (Dove @ Hollinsclough)	2.313	45	4.15	0.225	0.373	0.712
41020 (Bevern Stream @ Clappers Bridge)	2.386	51	13.66	0.205	0.171	0.915
39033 (Winterbourne Stream @ Bagnor)	2.43	58	0.401	0.342	0.382	1.076
Total		503				
Weighted Means				0.266	0.249	
H2 value	2.3818					
Goodness of Fit	Generalised Logistic			General Extreme Value		
	-0.1544			-1.3816		

Table 6.3: Permeable Adjusted L-CV and L-Skew

Station	Adjusted L-CV	Adjusted L-Skew
27073 (Brompton Beck @ Snainton Ings)	0.199	0.055

Station	Adjusted L-CV	Adjusted L-Skew
26016 (Gypsy Race @ Kirby Grindalythe)	0.283	0.313
26014 (Water Forlomes @ Driffield)	0.287	0.099

Appendix 3: Table of Hydraulic Structures

Network ID, Cross Section ID	Model Details	Photograph/Survey Section
UOW001_01475	Description: Normandy Way Culvert NGR: 442537, 295644 Domain: 1D ESTRY Unit Type: Circular Conduit (Double) Dimensions: 2 x 0.5m dia Upstream Invert Level: 108.71m AOD and 108.72m AOD Downstream Invert Level: Not surveyed Length: 81m Manning's N: 0.015 Blockage: 0% Spill/Bypass: Modelled in 2D domain	
UOW001_01321	Description: Access Bridge NGR: 442464, 295789 Domain: 1D ESTRY Unit Type: Irregular Culvert Upstream Invert Level: 106.88m AOD Downstream Invert Level: 106.67m AOD Length: 6m Manning's N: 0.020 Blockage: 0% Spill/Bypass: Modelled in 2D domain	
R2_00278	Description: Normandy Way Culvert NGR: 441843, 295428 Domain: 1D ESTRY Unit Type: Circular Culvert (Double) Dimensions: 2 x 0.45m dia Upstream Invert Level: Not surveyed Downstream Invert Level: 105.48 AOD Length: 306m Manning's N: 0.015 Blockage: 0% Spill/Bypass: Modelled in 2D domain	

Network ID, Cross Section ID	Model Details	Photograph/Survey Section
R2_00145	Description: Access Track Culvert NGR: 441766, 295522 Domain: 1D ESTRY Unit Type: Circular Culvert Dimensions: 0.6m dia Upstream Invert Level: 104.57m AOD Downstream Invert Level: 104.53m AOD Length: 7m Manning's N: 0.015 Blockage: 0% Spill/Bypass: Modelled in 2D domain	
R3_00139	Description: Access Track Culvert NGR: 441747, 295516 Domain: 1D ESTRY Unit Type: Circular Culvert Dimensions: 0.5m dia Upstream Invert Level: 103.89m AOD Downstream Invert Level: 103.88m AOD Length: 7m Manning's N: 0.015 Blockage: 0% Spill/Bypass: Modelled in 2D domain	
R4_00000	Description: Stoke Road Culvert NGR: 441697, 295593 Domain: 1D ESTRY Unit Type: Irregular Culvert Upstream Invert Level: 103.41m AOD Downstream Invert Level: Not surveyed Length: 19m (assumed) Manning's N: 0.020 Blockage: 0% Spill/Bypass: Modelled in 2D domain	

Appendix 4: Model Schematic

Notes

1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.

2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.

4. Any discrepancies noted on site are to be reported to the engineer immediately.

5. Model not yet peer reviewed.

6. OS Mapping has been reproduced under the license number 100022432.

7. This drawing is not suitable for construction purposes.

- Key
- 1D Domain
 - 1D Flow / Time (QT) Inflows
 - 1D Head / Time (HT) Boundary
 - 1D Sewer Manholes
 - 1D Pipes / Culverts
 - 1D Open Watercourse
 - 2D Domain
 - 2D Head / Flow (HQ) Boundary
 - 2D Watercourse Channel
 - Illustrative Site Boundary

P01	24.03.22	Preliminary Issue	MB	AP
Rev	Date	Details of issue / revision	Drw	Rev

Issues & Revisions

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Client

Richborough Estates Limited and Mr & Mrs Adcock

Project Title

Land East of Stoke Road and North of Normandy Way (A47), Hinckley

Drawing Title

Baseline Hydraulic Model Schematic

Drawn:	M. Brambani	Reviewed:	A. Petrakis
BWB Ref:	210683	Date:	24.03.22
		Scale@A1:	1:3000

Drawing Status

PRELIMINARY

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
HIN-BWB-ZZ-XX-DR-YE-0008	S2	P01

Appendix 5: Baseline Flood Maps