



FLOOD RISK MODELLING TECHNICAL NOTE

LAND AT PADGE HALL FARM, HINCKLEY

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CONTENTS

1.0	INTRODUCTION	4
2.0	PLANNING CONDITION 19	4
3.0	FLUVIAL FLOOD RISK MODELLING	5
4.0	COMMENTS IN RELATION TO INFORMATIVE NOTE NO.3	6
5.0	SUMMARY	6

APPENDICES

Appendix A	Hydraulic Modelling Study at Sketchley Brook
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1.0 INTRODUCTION

- 1.1 This technical note has been prepared to address planning condition 19 of the Land South Of The A5 Padge Hall Farm Hinckley Leicestershire planning application (Hinckley & Bosworth Borough Council reference: 21/01191/HYB) which concerns fluvial flood risk at the location of the road lowering works on the A5.
- 1.2 The planning application is a cross boundary application with Hinckley & Bosworth Borough Council (HBBC), Rugby Borough Council and Nuneaton and Bedworth Borough Council.

2.0 PLANNING CONDITION 19

- 2.1 Planning Condition 19 of the HBBC Decision Notice reads:

No development of the A5 road lowering works shall take place until an assessment of the fluvial flood risk to and resulting from this element of this scheme has been submitted to, and approved in writing, by the local planning authority (in consultation with the Environment Agency). The assessment shall also include:

1. *Confirmation of any fluvial flood risks to the road lowering (including suitable hydraulic modelling or calculations for all fluvial flood events up to the design flood event, including an allowance for climate change (2022 guidance).*
2. *Details of any mitigation measures required to overcome any fluvial flood risk issues. Any mitigation measures required shall be fully implemented prior to first use of the lowered road (A5) and subsequently in accordance with the scheme's timing/phasing arrangements. Any measures detailed above shall be retained and maintained thereafter throughout the lifetime of the development.*

Reason: To reduce the risk of fluvial flooding to the proposed development (A5 road lowering scheme) and to prevent flooding elsewhere by ensuring that any fluvial flood risk is appropriately managed in accordance with Policy DM7 of the adopted site allocations and development management policies development plan document (2016).

- 2.2 Planning Condition 19 is supported by the following Informative Note no.3:

The following information will need to be provided when Condition 19 is discharged (numbered to match the condition):

1. *It is recognised that the Environment Agency has given an indication of acceptance regarding the outfall into the Harrow Brook. At the detailed design stage, the LLFA will expect further details regarding this outfall and confirmation, ideally in the form of a Flood Risk Activities Permit (or confirmed exemption), as to the final approval of such design elements.*
2. *The strategy agreed to date may be treated as a minimum and further source control SuDS should be considered during the detailed design stages as part of a 'SuDS management train' approach to provide additional benefits and resilience within the design.*
 - a. *For the 'Full' site: further consideration should be given.*
 - i. *The design to date assumes a 'Medium' pollution hazard index however a 'High' may be considered more appropriate given such description includes haulage yards, highly frequented lorry approaches to industrial estates amongst others - justification will be required of the current designation.*

- ii. Hazard Mitigation Indices have been provided regarding the proposed interceptors and justification of these will be required at the detailed design stage in line with manufacture recommendations. The management train could be revisited to pass water through as many features as possible.*
 - iii. Pumps are required on the southern side of the Unit 1 building. Further details of these will be required and where feasible given levels, the LLFA suggest aboveground, shallow over the edge drainage combined with overland flow routing is used to minimise the area draining to the pumps.*
 - b. For the 'Outline' site, further details will be required demonstrating the use of above-ground SuDS, in line with the principles established as part of the 'full' application.*
- 3. *These should be feature-specific demonstrating that such the surface water drainage system(s) are designed in accordance with 'The SuDS Manual', CIRIA Report C753. Of note to consider:*
 - a. The location and design of sediment forebays.*
 - b. The design of the proposed surface water pumping from the dock levellers.*
- 4. *This should include:*
 - a. Suitable representation of the proposed drainage scheme, details of design criteria used (incl. relevant scenarios such as a surcharged outfall or pump failure), and justification of such criteria where relevant.*
 - b. Simulation of the network for a range of durations and return periods including the 1 in 2 year, 1 in 30 year and 1 in 100 year plus 40% climate change events*
 - c. Results should demonstrate the performance of the drainage scheme including attenuation storage, flows in line with agreed discharge rates, potential flood volumes and network status. Results should be provided as a summary for each return period.*
 - d. Evidence should be supported by a suitably labelled plan/schematic (including contributing areas) to allow suitable cross checking of calculations and the proposals.*
- 5. *Such overland flow routing should:*
 - a. Support the drainage strategy to date showing retention of flood volumes in proximity of the drainage channels and across the wider site, demonstrate how runoff will be directed through the development.*
 - b. Consider property finished floor levels and thresholds in relation to exceedance flows. The LLFA recommend FFLs are set to a minimum of 150mm above surrounding ground levels.*
 - c. Recognise that exceedance can occur during any storm event due to a number of factors therefore exceedance management should not rely on calculations demonstrating no flooding.*

3.0 FLUVIAL FLOOD RISK MODELLING

- 3.1 An assessment of the fluvial flood risk in relation to the A5 road lowering works has been undertaken. The source of potential fluvial flood risk to the A5 road lowering location is the Sketchley Brook to the south. The results of the fluvial modelling study are provided in the Hydraulic Modelling Study at Sketchley Brook, Hinckley (**Appendix A**).
- 3.2 The results of the fluvial modelling study show that the A5 road lowering works location is outside the 30-year, 100-year, and 1000-year fluvial modelled flood events. The nearest modelled flood extents to the road lowering location are situated approximately 130m south-west for the 1000-year flood event (Figure 3.1 in the Hydraulic Modelling Study).
- 3.3 Additionally, the fluvial hydraulic model was simulated for a 100-year plus 30% allowance for climate change (CC) event in line with the latest Environment Agency guidance for the higher central allowance. The higher central allowance was used in this study due to the A5 highway

where the work will take place being deemed as essential infrastructure. The 100-year plus climate change flood extents are less extensive than the 1000-year flood extents.

- 3.4 Therefore, the proposed A5 road lowering works are shown to lie outside areas at risk of fluvial flooding and will also not affect fluvial flood risk areas elsewhere. As such no mitigation measures in relation to fluvial flood risk are deemed necessary.
- 3.5 It should be noted that the flood risk modelling study also separately assesses the surface water flood risk at the A5 road lowering works location. The location is at a localised low point in the topography and surface water runoff is shown to collect at this point on the highway. However, a limitation of the surface water model is that it does not incorporate any below ground drainage systems so does not provide a drainage outlet to the low point of the highway, thereby not allowing the surface water to drain away from the low point which will occur in reality.
- 3.6 The results of the surface water modelling will be used to inform the drainage design of the A5 lowering works. However, the surface water flood risk is shown to have no impact on the fluvial flood risk extents.

4.0 COMMENTS IN RELATION TO INFORMATIVE NOTE NO.3

- 4.1 Informative Note no.3 requires details of the proposed drainage system, however it specifically refers to the wider onsite development drainage system, which is separate to the A5 road lowering works location, therefore is considered to only apply to that aspect of the development drainage system.
- 4.2 Taking each point in turn, point 1 refers to the outfall to the Harrow Brook from the development site drainage system, so is unrelated to the offsite A5 road lowering works which lie in the separate Sketchley Brook catchment further to the south.
- 4.3 Points 2 relates to the onsite development site drainage system and refers to specific areas of the development such as the haulage yards and southern side of Unit 1, requiring the drainage to incorporate Source Control SuDS as part of a SuDS Management Train.
- 4.4 Point 3 similarly relates to the onsite development site drainage system, requiring drainage systems to be in accordance with the SuDS manual.
- 4.5 Point 4 follows on from Point 3 and sets out the drainage design details that are required for the onsite development drainage system.
- 4.6 Point 5 requires details of overland flood routing and how flood volumes will be retained in proximity to drainage channels, whilst taking account of finished floor levels and thresholds, so again is in relation to the drainage around onsite buildings.

5.0 SUMMARY

- 5.1 This technical note provides the results of the fluvial flood risk modelling on the Sketchley Brook in the vicinity of the A5 road lowering works. The results show that the location of the A5 lowering works is not in a fluvial flood risk area and further mitigation works in respect of fluvial flood risk are not required.

- 5.2 The modelling study also separately assesses the surface water flooding at the A5 lowering works location and the results will be used to inform the detailed drainage design at this location, but the surface water flood risk is shown to have no impact on the fluvial flood risk extents.

APPENDIX A

HYDRAULIC MODELLING STUDY AT SKETCHLEY BROOK

Hydraulic Modelling Study at Sketchley Brook, Hinckley

Draft Report

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This report describes work commissioned by ADC Infrastructure Ltd, by an instruction dated 11th October 2023. The Client's representative for the contract was Richard Winn of ADC Infrastructure Ltd. Georgie Troy of JBA Consulting carried out this work.

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Contents

Executive Summary	ix
1 Introduction	11
1.1 Terms of reference	11
1.2 Site description	11
1.3 Proposal	12
1.4 General approach	12
2 Methodology	14
2.1 Data availability	14
2.2 Model extent and build	14
2.3 Model roughness	17
2.4 Model boundary conditions	18
2.5 Model performance	19
2.6 Model limitations	19
2.7 Sensitivity analysis	20
2.8 Model runs	20
3 Baseline Model Results	21
3.1 Baseline fluvial flood extents	21
3.2 Baseline surface water flood extents	26
4 Post Development Model Results	32
4.1 Post development scenario	32
4.2 Modelled flood extent	32
4.3 Depth impact analysis	33
4.4 Post development flood levels	33
4.5 Post development hazard to people classification	34
5 Conclusion and Recommendations	36
5.1 Conclusion	36
5.2 Recommendations	37
A Site Layout	39

B	Harrow & Sketchley Brooks Model Report (2013)	40
C	Channel Survey Data	41
D	Key Hydraulic Structures	42
E	Hydrology Report	46
F	Sensitivity Analysis	47
	F.1 Fluvial sensitivity analysis	47
	F.2 Surface water sensitivity analysis	49
G	Topographic Survey Data	52

List of Figures

Figure 2-1: Modelled 1D and 2D domains	15
Figure 2-2: Model ground levels (m AOD)	16
Figure 3-1: Baseline fluvial flood extents (30-year, 100-year, 1000-year)	21
Figure 3-2: Baseline 100-year fluvial flood extent plus 30% climate change	22
Figure 3-3: 100-year plus 30% climate change fluvial flood depths	23
Figure 3-4: 100-year plus 30% climate change fluvial flood levels	24
Figure 3-5: 100-year plus 30% climate change Hazard-to-People Classification	25
Figure 3-6: Baseline surface water extents (30-year, 100-year, 1000-year)	26
Figure 3-7: Baseline 100-year surface water flood extent plus 40% climate change	27
Figure 3-8: 100-year plus 40% climate change surface water flood depths	28
Figure 3-9: 100-year plus 40% climate change surface water flood depths (enlarged)	29
Figure 3-10: 100-year plus 40% climate change surface water flood levels	30
Figure 3-11: 100-year plus 40% climate change surface water Hazard-to-People Classification	31
Figure 4-1: Post development surface water flood extent for 100-year plus 40% climate change	32
Figure 4-2: Depth impact analysis on the baseline 100-year plus 40% climate change and post development flood depths	33

Figure 4-3: Post development scenario flood levels for the 100-year plus 40% climate change	34
Figure 4-4: Post development scenario 100-year plus 40% climate change surface water Hazard-to-People Classification	35
Figure E 1: Fluvial sensitivity analysis for +20% roughness	47
Figure E 2: Fluvial sensitivity analysis for +250mm increase at the downstream boundary	48
Figure E 3: Fluvial sensitivity analysis for +20% flow	49
Figure E 4: Surface water sensitivity analysis for +20% roughness	50
Figure E 5: Surface water sensitivity analysis for +20% flow	51

List of Tables

Table 1-1: Summary of site details	12
Table 2-1: Manning's 'n' range within the hydraulic model	18
Table 2-2: Peak fluvial flows	18
Table 3-1: Defra's FD2321/TR2 "Flood Risks to People" Classification	25

Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
AONB	Area of Outstanding Natural Beauty
CC	Climate Change
DEFRA	Department of the Environment, Food and Rural Affairs (formerly MAFF)
dVol	Change in volume in the TUFLOW model since the previous time (m ³)
EA	Environment Agency
FRA	Flood Risk Assessment
HM	Hydraulic Model
JFLOW	2-D hydraulic modelling package developed by JBA
LiDAR	Light Detection And Ranging
NGR	National Grid Reference
OS	Ordnance Survey
TUFLOW	Two-dimensional Unsteady FLOW (a hydraulic model)

Executive Summary

JBA Consulting (JBA) were commissioned by ADC Infrastructure Ltd to undertake a fluvial and surface water hydraulic modelling study of the Sketchley Brook to inform a highway improvement scheme along a section of the A5 in Hinckley, Leicestershire. The Sketchley Brook is located to the south of the section of the A5 (Watling Street) where highway improvements are due to take place.

The purpose of the study is to increase the understanding of the fluvial and surface water flood risk at the site and to surrounding third party land. To achieve this a 1D-2D Flood Modeller-TUFLOW hydraulic model of the watercourse and floodplain was obtained from the Environment Agency and updated to allow accurate representation of flood levels, extents, velocities and hazard to people. The model extent includes the site and the Sketchley Brook to the south and east of the site in order to refine the understanding of flood mechanisms.

The proposal is to improve sections of the A5 in Hinckley. The potential highway works comprise minor lowering of the carriageway where the A5 crosses beneath a railway bridge.

The lowering of the carriageway location, hereafter referred to as 'the site', is situated at its closest point, approximately 245m north of the Sketchley Brook. To the east of the site, the Sketchley Brook meanders frequently but generally flows in a south-westerly direction before converging with the River Anker approximately 2.3km south-west of the site. The Ashby de la Zouch canal crosses the Sketchley Brook approximately 695m east of the site.

The fluvial hydraulic model was simulated for the 30-year (3.3% AEP), 100-year (1% AEP) and 1000-year (0.1% AEP) fluvial events. Additionally, a 100-year plus 30% allowance for climate change (CC) event was simulated in line with the latest Environment Agency guidance for the higher central allowance in the 2080's epoch. The higher central allowance was used in this study due to the site being deemed as essential infrastructure.

The surface water hydraulic model was simulated for the 30-year, 100-year and 1000-year surface water events. Additionally, a 100-year plus 40% allowance for climate change event was simulated in line with the latest Environment Agency guidance for the upper end allowance in the 2070's epoch. A one-hour critical storm duration was used when simulating these events as it produced the highest flood depths compared to the three and six-hour storm durations.

A review into the model's sensitivity to changes in flow, roughness and downstream boundary parameters has been undertaken. The fluvial model is sensitive to increases in flow but is not sensitive to increases in roughness and downstream boundary conditions. The surface water model is not sensitive to increases in flow and roughness.

Baseline model results indicate that:

- The site is outside of the 30-year, 100-year, 100-year plus 30% CC, and 1000-year modelled fluvial extents.

- The site experiences flooding during the 30-year, 100-year, 100-year plus 40% CC, and 1000-year modelled surface water events.
- During the modelled 100-year plus 40% CC surface water event, peak flood levels reach 89.13m AOD along the A5 beneath the railway bridge.
- During the modelled 100-year plus 40% CC surface water event, the hazard rating at the site is predicted to range from 'caution' to 'danger for some'. There are small, isolated areas of 'danger for most' along this stretch of the A5, however, these are minimal.

A post development scenario was run for the 100-year plus 40% CC surface water event to evaluate flood risk as a result of the proposed development, including proposed mitigation. As no fluvial flooding is predicted at the site during all modelled fluvial flood events, it was not necessary to simulate a post development fluvial scenario. In this study, the post development scenario involved the lowering of the A5 carriageway beneath the railway bridge. During the post development 100-year plus 40% CC surface water flood event, the detailed hydraulic modelling results show:

- Flooding will extend further along the A5 compared to the baseline scenario by approximately 26m in the north-westerly direction and 38m in the south-easterly direction. However, the changes in road level do not increase flood risk across third party land to the north and south of the carriageway.
- There is an increase in flood depths of approximately 0.32m along the section of the A5 where the proposed lowering of the carriageway is to take place. There is also a decrease in flood depths of approximately 0.11m to land adjacent to the A5 to the north, showing third party land will not be detrimentally impacted by these proposed works.

The increase in flood depth during the post development scenario is expected. This is due to:

- the lowering of the carriageway taking place at an existing low point and;
- the baseline and proposed surface water modelling scenarios not taking account of the highway drainage proposal that serves to drain surface water in the vicinity of the carriageway beneath the railway bridge. This will be assessed separately by ADC Infrastructure Ltd.

It is recommended to validate results from this hydraulic modelling study with the Environment Agency as part of the planning process. The hydraulic modelling results should be used to inform a site-specific Flood Risk Assessment (FRA) for the site.

1 Introduction

1.1 Terms of reference

JBA Consulting (JBA) were commissioned by ADC Infrastructure Ltd to undertake a fluvial and surface water hydraulic modelling study of the Sketchley Brook to inform a highway improvement scheme along a section of the A5 in Hinckley, Leicestershire. Appendix A shows the entire planning application boundary, however, for the purposes of this study, the boundary has been trimmed to the section of the A5 which crosses beneath the railway bridge. The Sketchley Brook is located to the south of the section of the A5 (Watling Street) where highway improvements are due to take place.

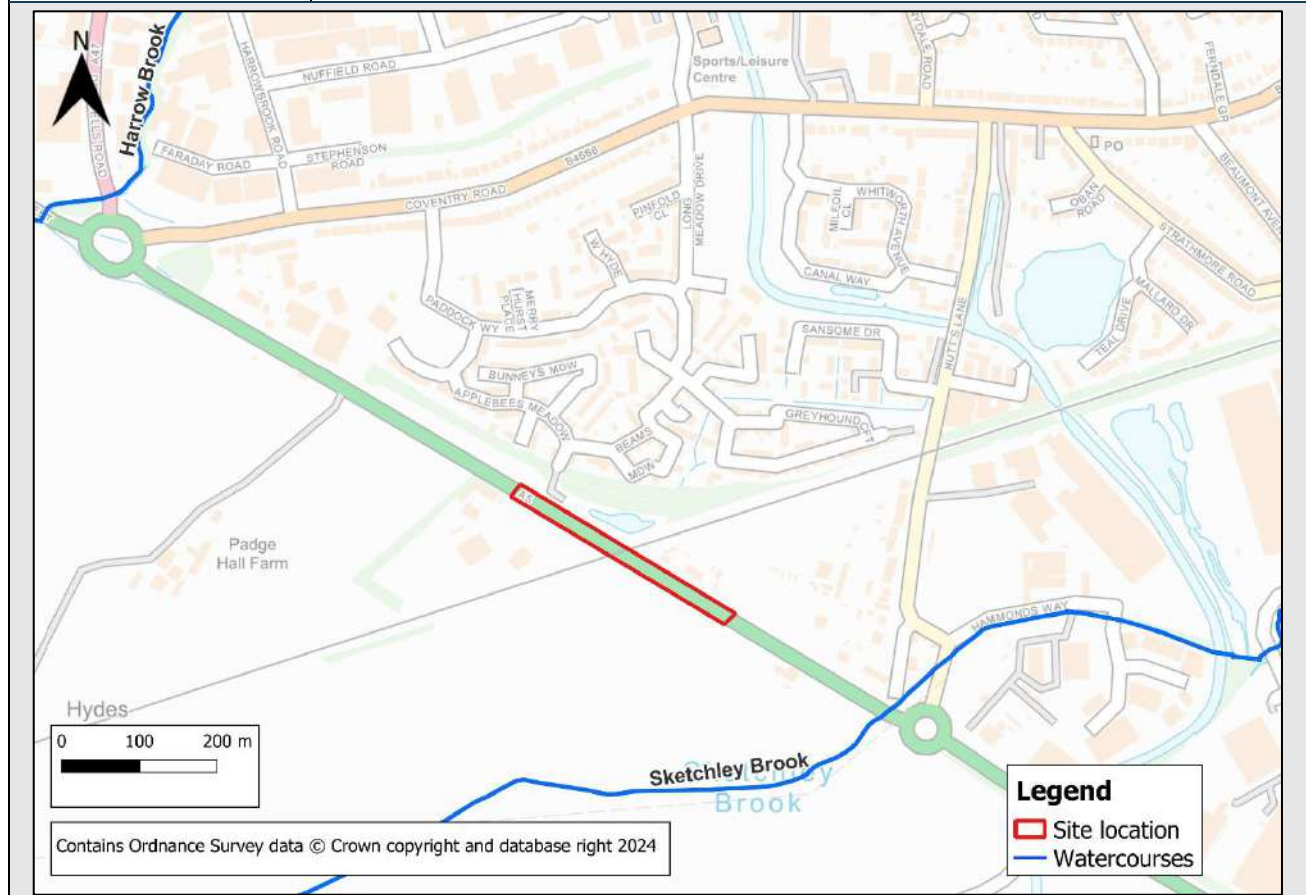
The purpose of the study is to increase the understanding of the fluvial and surface water flood risk at the site and to surrounding third party land. To achieve this a 1D-2D Flood Modeller-TUFLOW hydraulic model of the watercourse and floodplain was obtained from the Environment Agency and updated to allow accurate representation of flood levels, extents, velocities and hazard to people.

1.2 Site description

The site is situated at its closest point, approximately 245m north of the Sketchley Brook. To the east of the site, the Sketchley Brook meanders frequently but generally flows in a south-westerly direction before converging with the River Anker approximately 2.3km south-west of the site. The Ashby de la Zouch canal crosses the Sketchley Brook approximately 695m east of the site.

Table 1-1: Summary of site details

Site address	Section of A5 (Watling Street) that crosses a railway bridge, Hinckley.
Site area	0.63 hectares
Existing land-use	Major road
OS-NGR	SP 40608 92700
Country	England
County	Leicestershire



1.3 Proposal

The proposal is to improve sections of the A5 in Hinckley. The potential highway works comprise minor lowering of the carriageway where the A5 crosses beneath a railway bridge.

1.4 General approach

A 1D-2D hydraulic model was developed using the Flood Modeller-TUFLOW modelling packages. The model extent includes the site and the Sketchley Brook in order to refine the understanding of flood mechanisms.

It is understood that Flood Zones shown in relation to the site on the Environment Agency Flood Map for Planning (FMfP) are derived from broadscale generalised hydraulic

modelling, such as JFLOW. These broadscale models are known to typically have a conservative flood extent and do not explicitly model the channel capacity, or structures within the watercourse. The broadscale modelling is not appropriate for the assessment of flood risk at a site-specific level.

To inform this study, a copy of the existing 2013 Harrow and Sketchley Brook Flood Modeller-TUFLOW model was obtained from the Environment Agency. The 2013 Harrow and Sketchley Brook hydraulic modelling report can be found in Appendix B of this report. In order to create a model suitable for a site-specific assessment, the model was trimmed to more accurately represent flood risk in the vicinity of the site. Channel survey of specific sections along the Sketchley Brook was undertaken by Grantham Coates Survey Limited in October 2023. These sections included the points where the Sketchley Brook crosses the Ashby de la Zouch canal and the A5. This survey data was used to update the representation of the channel and structures at key locations within the 1D model domain. Topographic survey data and publicly available LiDAR data was used to represent ground levels within the 2D model extent (floodplain).

Hydrographs were derived for the 30-year, 100-year, 100-year plus 30% CC, and 1000-year fluvial flood events. These hydrographs were applied directly to the model to provide an assessment of the baseline model flood risk conditions of the site.

Hyetographs were also derived for the 1-hour, 3-hour and 6-hour storm durations for the 30-year, 100-year, 100-year plus 40% CC, and 1000-year surface water flood events. Separate rural and urban hyetographs were generated to account for rural and urban areas within the model, with the urban hyetographs accounting for rainfall losses due to sewers. A critical storm duration of one-hour was then determined based on the 100-year event.

In line with best practice, the model's sensitivity to roughness, flow and downstream boundary parameters were tested to improve confidence in the model results.

2 Methodology

2.1 Data availability

As the Sketchley Brook had previously been modelled in 2013 (see Appendix B for the original report), it was not necessary to obtain new survey data for the entirety of this watercourse within the model extent. Grantham Coates Surveys Limited collected hard bed channel cross-section data for 5 cross sections along the Sketchley Brook at key hydraulic structures. This survey was conducted in October 2023 and is included in Appendix C.

DEFRA LiDAR was obtained from the Open Data website to represent ground levels within the wider flood plain. The LiDAR has a grid resolution of 1m and was last flown in 2020. Additionally, topographic survey data for the current and proposed scenarios at the site and surrounding area was provided to gain a more accurate understanding of ground levels. Appendix G shows the topographic survey for current ground levels.

2.2 Model extent and build

A 1D-2D Flood Modeller-TUFLOW model of the Sketchley Brook was obtained from the Environment Agency, trimmed and updated to more accurately represent flood risk in the vicinity of the site. The model was simulated using the Flood Modeller version 5.1.0 and TUFLOW version 2020-10-AD-iDP-w64.

The channel was represented within the 1D domain using Flood Modeller. Channel cross sections were taken from the 2013 Harrow and Sketchley Brook Flood Modeller-TUFLOW hydraulic model, and from the channel survey data collected by Grantham Coates Surveys Limited in October 2023. The 1D Flood Modeller model, shown in Figure 2-1 covers approximately 3.1km of watercourse within the vicinity of the site. Detailed information on the newly surveyed hydraulic structures within the model are provided as part of Appendix D.

Channel cross sections were trimmed to the top of bank and linked to the 2D domain representing the floodplain. The 2D TUFLOW fluvial domain has an area of approximately 596ha whilst the surface water domain has an area of approximately 952ha. These domains are represented with a 4m grid resolution. Topographic survey data and LiDAR data was used to inform the model topography across the wider floodplain. Bank levels were represented using a 2D Z line which used surveyed bank levels from the 1D channel survey as well as topographic and LiDAR data along areas between surveyed cross-sections.

The extents of the 1D and 2D model domains are shown in Figure 2-1 below.

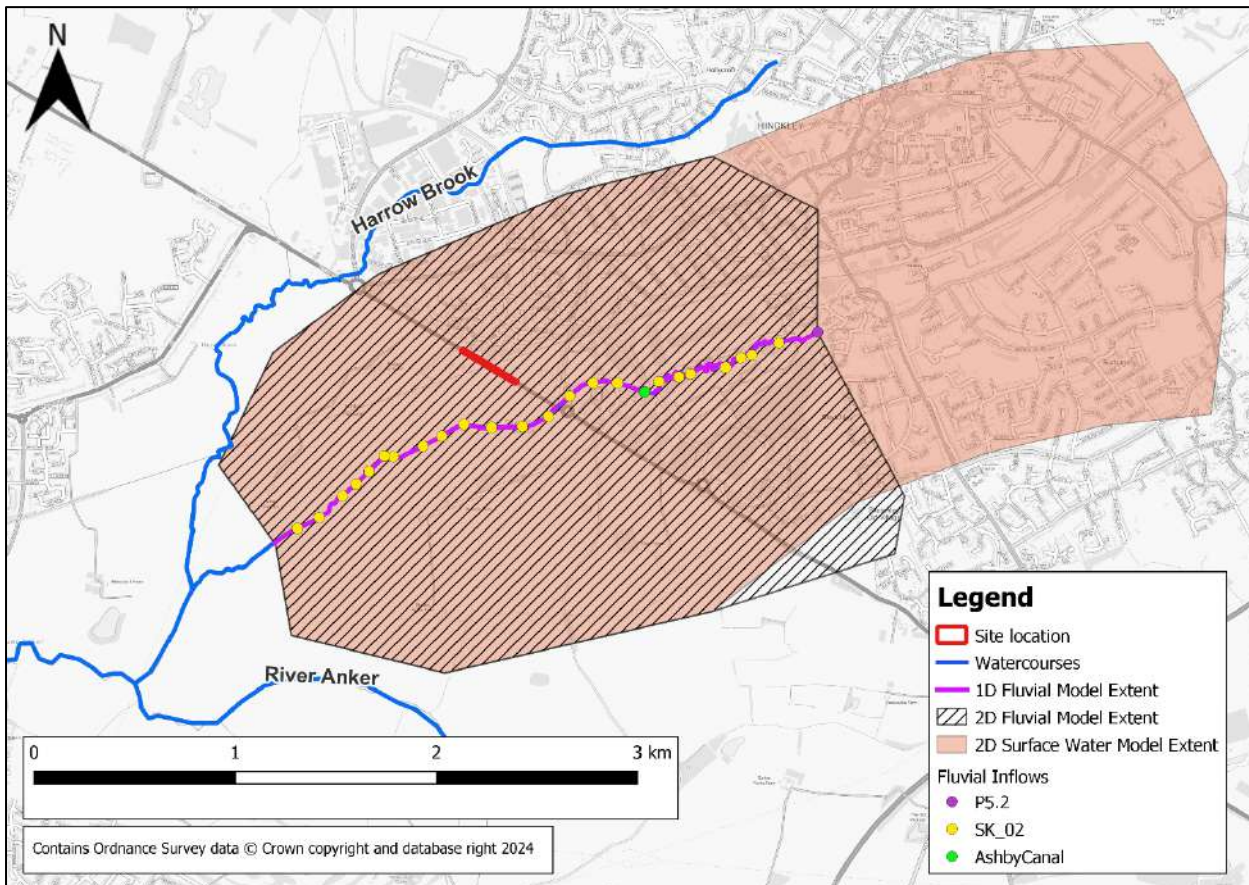


Figure 2-1: Modelled 1D and 2D domains

Figure 2-2 below shows the current ground levels, represented using topographic survey data (2023) and LiDAR data (2020). It shows that the minimum elevation of the section of the A5 beneath the railway bridge is approximately 88.67m AOD.



Figure 2-2: Model ground levels (m AOD)

2.2.1 Amendments made to the 2013 Harrow & Sketchley Brook EA model

2.2.1.1 Fluvial model amendments

The following list details the updates made to the original EA model for the purposes of simulating the fluvial model for this study:

- Trimmed the model to only include nodes P5.2 - 1.006 as flooding from other parts of these watercourses would not have been in close proximity to the site and surrounding area of interest.
- Updated hydrology was produced using the ReFH2 method for the new upstream of the model (P5.2) and the lateral inflow (SK_02). These have been represented as flow-time hydrographs within the model.
- New channel survey data was collected in October 2023 for five cross sections to provide a better representation of channel capacity, bank levels and structures. This data was collected at key structural locations along the sections of the Sketchley Brook which were deemed locations which could have a potential impact on flood risk to the site.
- The ground levels within the 2D domain were updated using publicly available LiDAR data (2020) as well as topographic survey data (2023) which was local to the site.

- The grid cell size was updated from 5m to 4m. As a result, it was necessary to alter the representation of some of the original model's structural overtopping from 1D to 2D.
- Several structures which had originally been represented with an arch bridge unit in Flood Modeller have been altered to a USBPR unit due to the geometry suggesting these have flat soffits.
- Whilst in the 2013 model the SK_02 lateral inflow was only connected to three river section nodes, the number of river section nodes connected to this inflow has been increased to 23 and has been distributed more evenly throughout the model, with each of these river section nodes contributing between 3.4% - 5.3% of the overall lateral inflow.
- Due to the presence of a drainage ditch to the south of the site which converges with the Sketchley Brook, it was deemed appropriate to remove a section of the Z-SHAPE bank line along the section of the Sketchley Brook where the ditch converges with this watercourse. This was to allow the 1D-2D link to pick up the lower elevations at this location.
- Materials files for the 2D domain were updated to take into account any significant changes in land use since 2013. Updates were made using aerial imagery and OS Zoomstack mapping.

2.2.1.2 Surface water model amendments

The following list details the updates made to the original EA model for the purposes of simulating the surface water model for this study:

- The fluvial updates to the original 2013 Harrow & Sketchley Brook EA model, which are detailed in section 2.2.1.1, were applied to this study's surface water model.
- Updated hydrology was produced using the ReFH2 method. Separate rural and urban hyetographs were generated to account for rural and urban areas within the model, with the urban hyetographs accounting for rainfall losses due to sewers.
- Two rainfall polygons were added to the 2D domain to represent the urban and rural hyetograph extents.
- The 2D domain was extended for this surface water model to allow for better representation of overland flow routes within, and surrounding, the site.
- The hydrology for the 2-year fluvial flood event was used for the watercourse inflow to allow all surface water simulations to run.

2.3 Model roughness

Manning's "n" values were used to represent the roughness between both the 1D channel and 2D floodplain.

The values of the 1D roughness were based on the data already provided within the 2013 Harrow and Sketchley Brook model, as well as photographs provided by Grantham Coates

Surveys Limited within the channel survey document. Manning's 'n' values in the floodplain were set to represent different land uses within the model extent. Land uses were defined using OS mapping.

Table 2-1: Manning's 'n' range within the hydraulic model

Features	Manning's 'n' value assigned
Buildings	0.3
Woodland	0.1
Roads and Tracks	0.025
Railway	0.035
General surface	0.06
Channel roughness	0.04 to 0.065

2.4 Model boundary conditions

2.4.1 Fluvial model inflows

A hydrological assessment was carried out in order to derive updated peak flow estimates for the Sketchley Brook. The full hydrological assessment is included in Appendix E. Flow-time hydrographs were derived for the 30-year, 100-year, 100-year plus 30% CC, and 1000-year fluvial flood events.

Climate change allowances were applied in line with the latest 2022 Environment Agency Guidance, with the 100-year flows uplifted by 30% (ref: Higher Central allowances for the 2080's epoch, Tame, Anker and Mease Management Catchment). The Higher Central allowance has been applied due to the carriageway works on the A5 being deemed as development to essential infrastructure.

Flow-time hydrographs were used in Flood Modeller to represent each model inflow. Updated hydrology was provided for the upstream inflow (P5.2) and the lateral inflow (SK_02). The latter was applied to 23 cross sections which are evenly distributed throughout the model to represent flow in the intervening area of the model. The existing EA model also contained a flow time hydrograph inflow for the Ashby de la Zouch canal which crosses the Sketchley Brook approximately 700m east of the site. Due to there being no updated hydrology for this inflow, a small flow of 0.2m³/s has been applied. The locations of these inflows are shown in Figure 2-1. The peak flows during each return period are detailed in Table 2-2.

Table 2-2: Peak fluvial flows

Inflow	30-year (m ³ /s)	100-year (m ³ /s)	100-year +30% climate change (m ³ /s)	1000-year (m ³ /s)
P5.2	3.62	4.56	5.93	7.88
SK_02	2.73	3.44	4.47	6.00

2.4.2 Surface water hyetographs

Surface water hyetographs were estimated for the 1-hour, 3-hour and 6-hour storm durations for the 30-year, 100-year, 100-year plus 40% CC, and 1000-year flood events. Separate rural and urban hyetographs were produced to account for the rural and urban areas within the model, with the urban hyetographs accounting for rainfall loss to sewers. The critical storm duration, which produces the deepest flood depths, was determined for the 100-year flood event, and then applied to the other flood events. The hydrology for the 2-year fluvial flood event was used for the watercourse inflow to allow all surface water simulations to run.

2.4.3 Downstream boundary conditions

The downstream boundary of the model is located approximately 1.3km south-west of the site. A normal depth boundary was applied in the 1D domain at the downstream extent of the modelled watercourse.

In the 2D domain, two HQ (flow-stage) lines based on the average slope in the floodplain at the downstream end of the model were used to represent the downstream boundary conditions in the 2D domain.

2.5 Model performance

No 2D negative depths are reported during the model simulations. The 2D peak Cumulative Mass Error within the model results is, however, outside of the normally acceptable range of +/-1%, peaking at -15.11% in the 30-year event. This occurs within the first few hours of the simulation when out of bank flooding begins to occur and is therefore attributed to the initial wetting of the 2D domain. Mass Error then reduces to at or below -1% and is within acceptable ranges during the peak of the event.

2.6 Model limitations

Survey data for the existing EA 2013 model was not available at the time of producing this modelling study. The representation of open channel sections and structures (e.g. geometry and mannings roughness) could not be fully reviewed. This has therefore limited the ability to sense check and improve the existing model. Specific limitations are detailed as follows:

- **SKBR_14 spill over the Ashby de la Zouch canal:** whilst a 2D spill with HX lines along the canal embankment crest has been used as a representation of overtopping, this does not accurately represent the interaction with the canal, which is not explicitly modelled.
- **1.025 culvert at Hammonds Way:** the structure's opening is skewed to the direction of the channel and it is not clear whether this is accounted for in the existing 2013 model due to the absence of original survey data.
- This study does not account for alterations to the highway drainage proposal and/or its impact on discharges or flows into the receiving ditch downstream. This will be assessed separately by ADC Infrastructure Ltd.

It is important to note that whilst these issues have been flagged in this report, it is considered that these will not significantly impact the model results.

2.7 Sensitivity analysis

A review into the model's sensitivity to changes in flow, roughness and downstream boundary parameters has been undertaken in line with best practice. The fluvial model is sensitive to increases in flow but is not sensitive to increases in roughness and changes in downstream boundary conditions. The surface water model is not sensitive to increases in flow and roughness. The roughness parameters and inflows have been checked and follow best practice and are therefore considered to be appropriate for the modelling. This provides confidence in the results of the modelling. Further details of the sensitivity analysis can be found in Appendix F.

2.8 Model runs

The following fluvial flood scenarios were simulated for the Sketchley Brook model:

- [Baseline scenario] – 30-year event
- [Baseline scenario] – 100-year event
- [Baseline scenario] – 100-year plus 30% climate change event
- [Baseline scenario] – 1000-year event
- [Sensitivity analysis] – 100-year flood event with [+ 20%] increase in roughness
- [Sensitivity analysis] – 100-year flood event with [+ 250mm] increase in peak water level at the downstream model boundary.
- [Sensitivity analysis] – 100-year flood event with [+20%] increase in flow

Although data was provided for the post development scenario, this simulation was not run due to the baseline fluvial flood events not entering the site.

The following surface water flood scenarios were simulated for the Sketchley Brook:

- [Baseline scenario] - 30-year event 1-hour critical storm duration
- [Baseline scenario] - 100-year event 1-hour critical storm duration
- [Baseline scenario] - 100-year plus 40% climate change event 1-hour critical storm duration
- [Baseline scenario] - 1000-year event 1-hour critical storm duration
- [Sensitivity analysis] - 100-year flood event with [+ 20%] increase in roughness
- [Sensitivity analysis] - 100-year flood event with [+ 20%] increase in flow
- [Post development] - 100-year with 40% climate change event 1-hour critical storm duration

3 Baseline Model Results

3.1 Baseline fluvial flood extents

Baseline flood extents for the 30-year, 100-year and 1000-year fluvial events are shown in Figure 3-1. This shows that the site is outside of the 30-year, 100-year, and 1000-year fluvial modelled flood events for the baseline scenario. The nearest flooding to the site is situated approximately 130m south-west of the site during the 1000-year flood event.

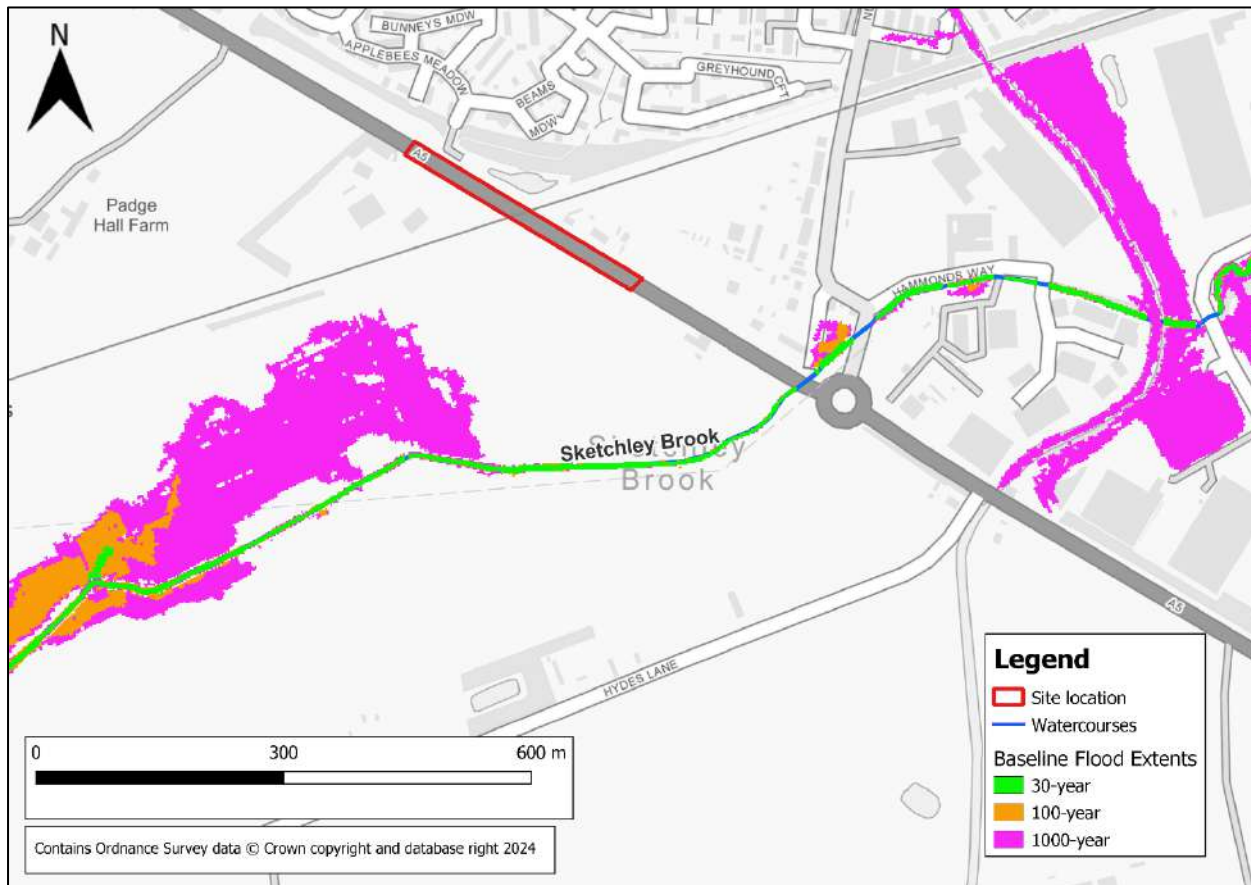


Figure 3-1: Baseline fluvial flood extents (30-year, 100-year, 1000-year)

The 100-year plus 30% climate change peak modelled fluvial flood extent is shown in Figure 3-2.

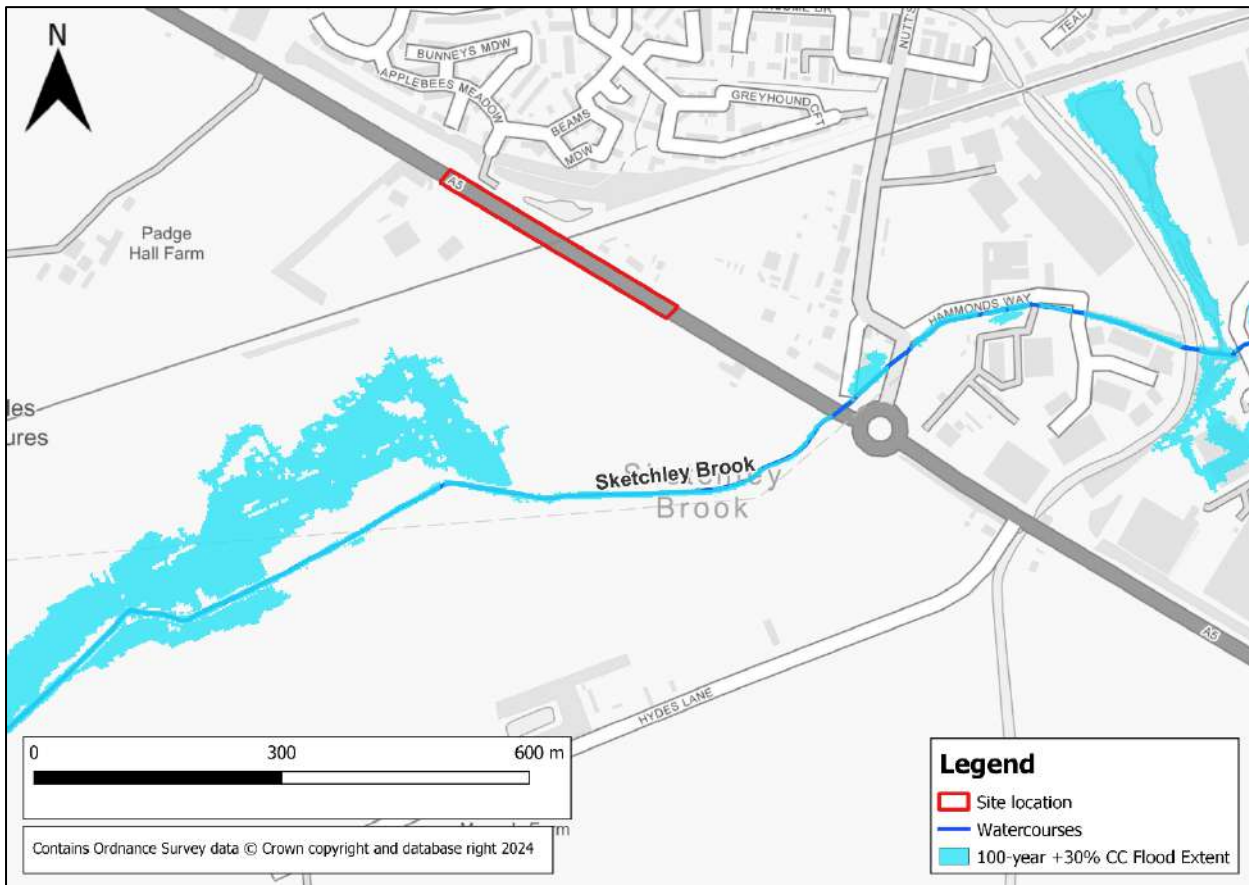


Figure 3-2: Baseline 100-year fluvial flood extent plus 30% climate change

Figure 3-2 shows that the site is outside of the 100-year with 30% climate change fluvial flood extent. The nearest flooding to the site during this event occurs approximately 150m south-west of the site.

3.1.1 Peak modelled flood depths

The peak modelled flood depths during the 100-year plus 30% climate change fluvial flood event are shown in Figure 3-3.

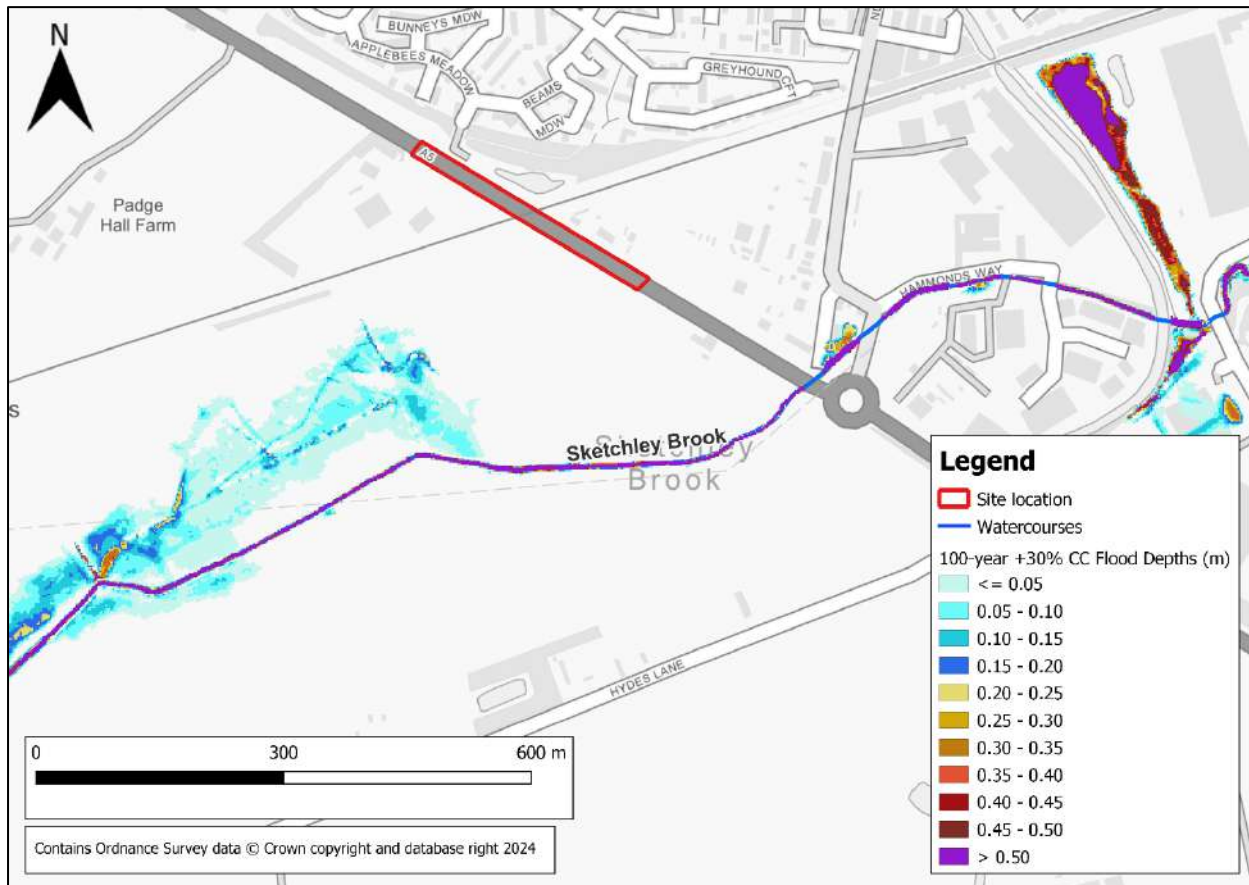


Figure 3-3: 100-year plus 30% climate change fluvial flood depths

Figure 3-3 indicates flood depths of between 0.01m and 0.26m will be observed approximately 150m south-west of the site.

3.1.2 Peak modelled flood levels

The peak modelled flood levels during the 100-year plus 30% climate change fluvial flood event are shown in Figure 3-4.

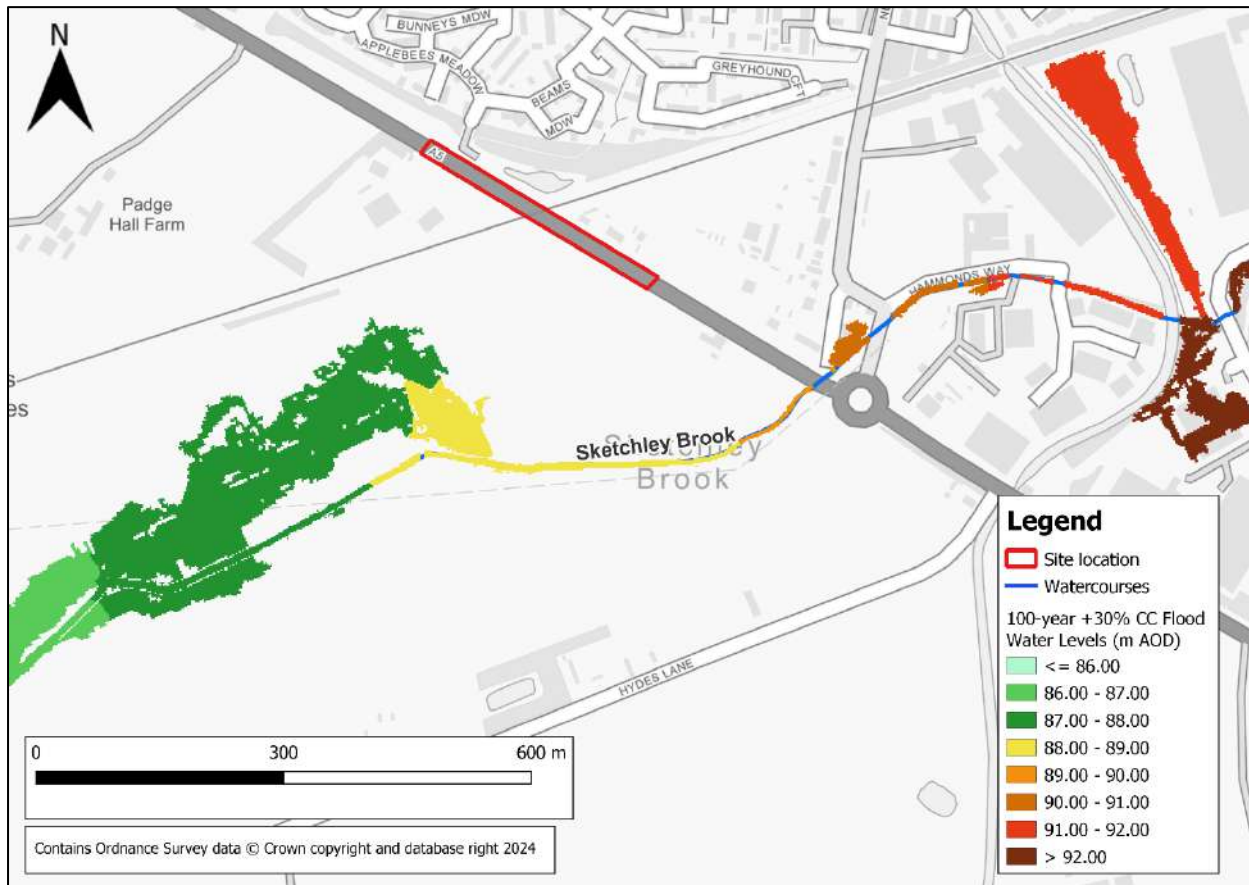


Figure 3-4: 100-year plus 30% climate change fluvial flood levels

Figure 3-4 shows that the 100-year plus 30% climate change fluvial flood level reaches a maximum of 87.96m AOD to the south-west of the site where the flood extent is closest to the site.

3.1.3 Hazard-to-people classification

The fluvial hazard-to-people classification during the 100-year plus 30% climate change event has been mapped using the formula as suggested in Defra's FD2321/TR2 "Flood Risk to People". The different hazard categories are shown in Table 3-1 and the Hazard Classification at the site during the 100-year plus 30% climate change fluvial event is shown in Figure 3-5.

Table 3-1: Defra's FD2321/TR2 "Flood Risks to People" Classification

Flood hazard rating depth x (velocity+0.5) +DF	Level of Flood Hazard Description	Class label
<0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 to 1.25	Moderate	Dangerous for some (i.e. Children) "Danger: flood zone with deep or fast flowing water"
1.25 to 2.00	Significant	Dangerous for most "Danger: flood zone with deep fast flowing water"
>2.00	Extreme	Dangerous for all "Extreme danger: flood zone with deep fast flowing water"

Using the hazard equation $HR = d \cdot (v + 0.5) + DF$

Where d = depth of flooding (m) v = velocity of floodwaters (m/sec) DF = debris factor

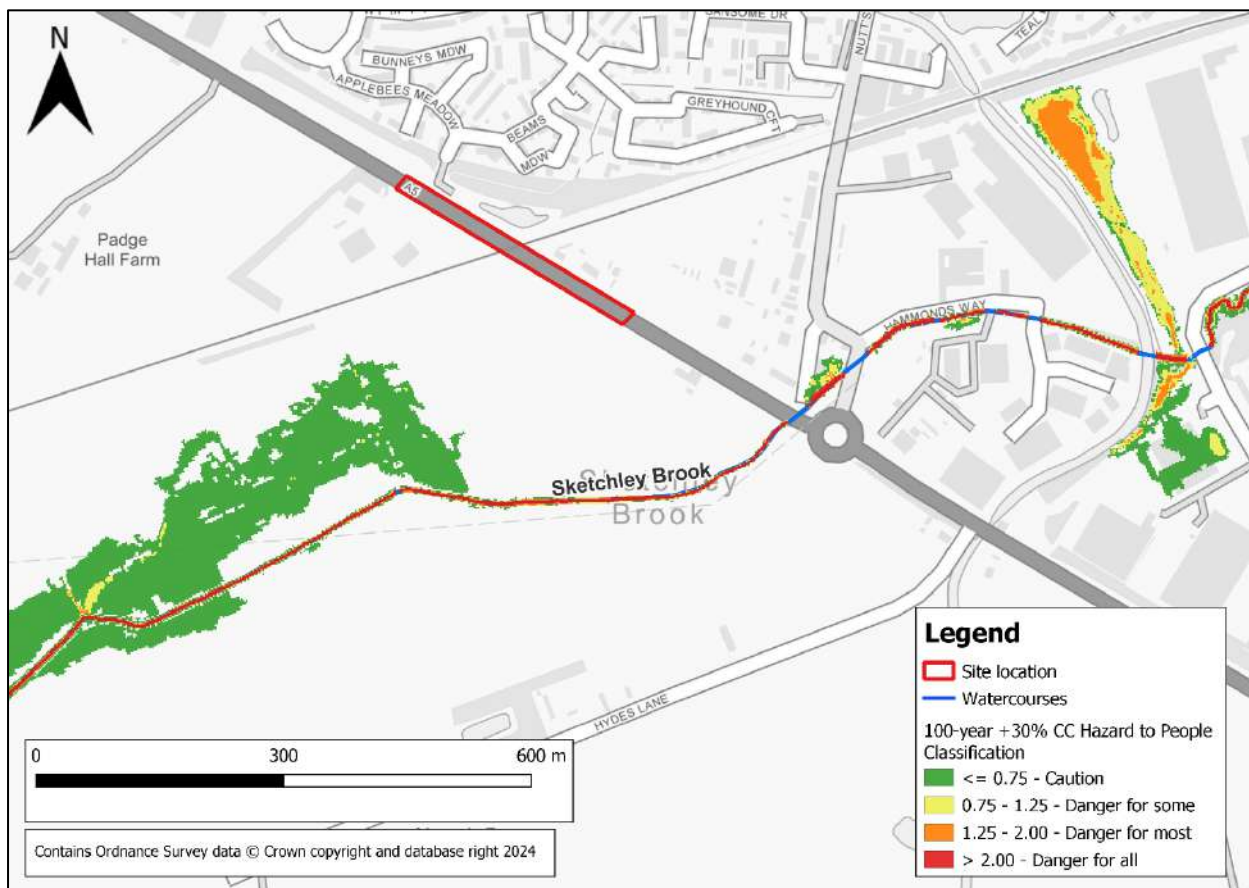


Figure 3-5: 100-year plus 30% climate change Hazard-to-People Classification

Figure 3-5 shows that during the 100-year plus 30% climate change fluvial flood event the site has a very low Hazard-to-People Classification. The nearest flooding to the south-west

of the site has a 'caution' Hazard to People Classification. The 'danger for most' and 'danger for all' classifications are predominantly confined within the Sketchley Brook channel and the body of water adjacent to the Ashby de la Zouch canal, located approximately 620m east of the site.

3.2 Baseline surface water flood extents

Baseline flood extents for the 30-year, 100-year and 1000-year surface water events are shown in Figure 3-6. This shows that flooding is predicted within the site during all modelled surface water flood events. With the exception of the ditches running parallel to the north and south of the railway embankment, there are no overland flow routes through the site.



Figure 3-6: Baseline surface water extents (30-year, 100-year, 1000-year)

The 100-year plus 40% climate change peak modelled surface water flood extent is shown in Figure 3-7.

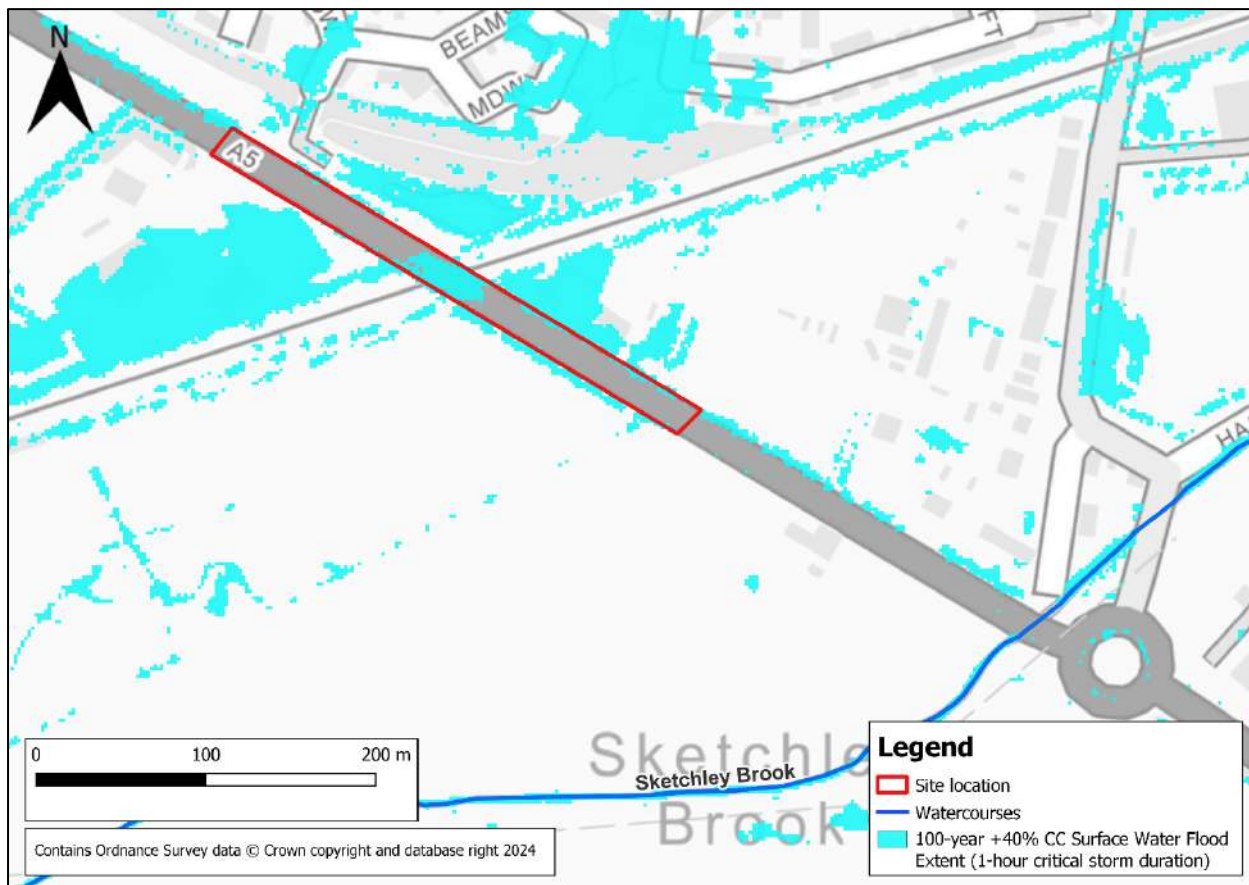


Figure 3-7: Baseline 100-year surface water flood extent plus 40% climate change

Figure 3-7 shows surface water ponding during the 100-year plus 40% climate change surface water flood extent. Flooding occurs beneath the railway bridge along the A5 as well as along both verges of this road.

The surface water modelling does not take account of the alterations to the highway drainage proposal that serves to drain surface water in the vicinity of the carriageway beneath the railway bridge. This will be assessed separately by ADC Infrastructure Ltd.

3.2.1 Peak modelled flood depths

The peak modelled flood depths during the 100-year plus 40% climate change surface water flood event are shown in Figure 3-8.

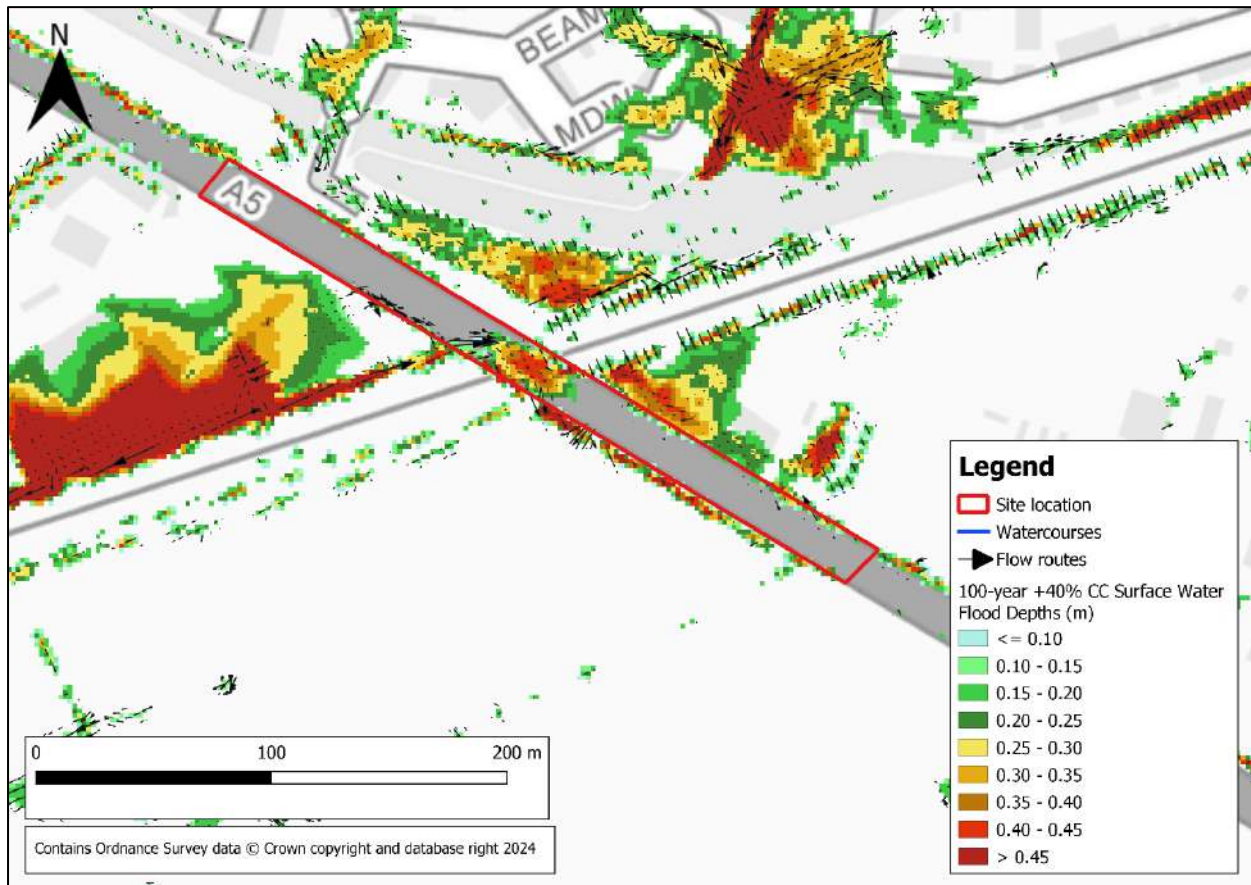


Figure 3-8: 100-year plus 40% climate change surface water flood depths

The peak modelled flood depths during the 100-year plus 40% climate change surface water flood event is also shown in Figure 3-9. This shows the location at which the A5 crosses beneath the railway bridge in more detail.

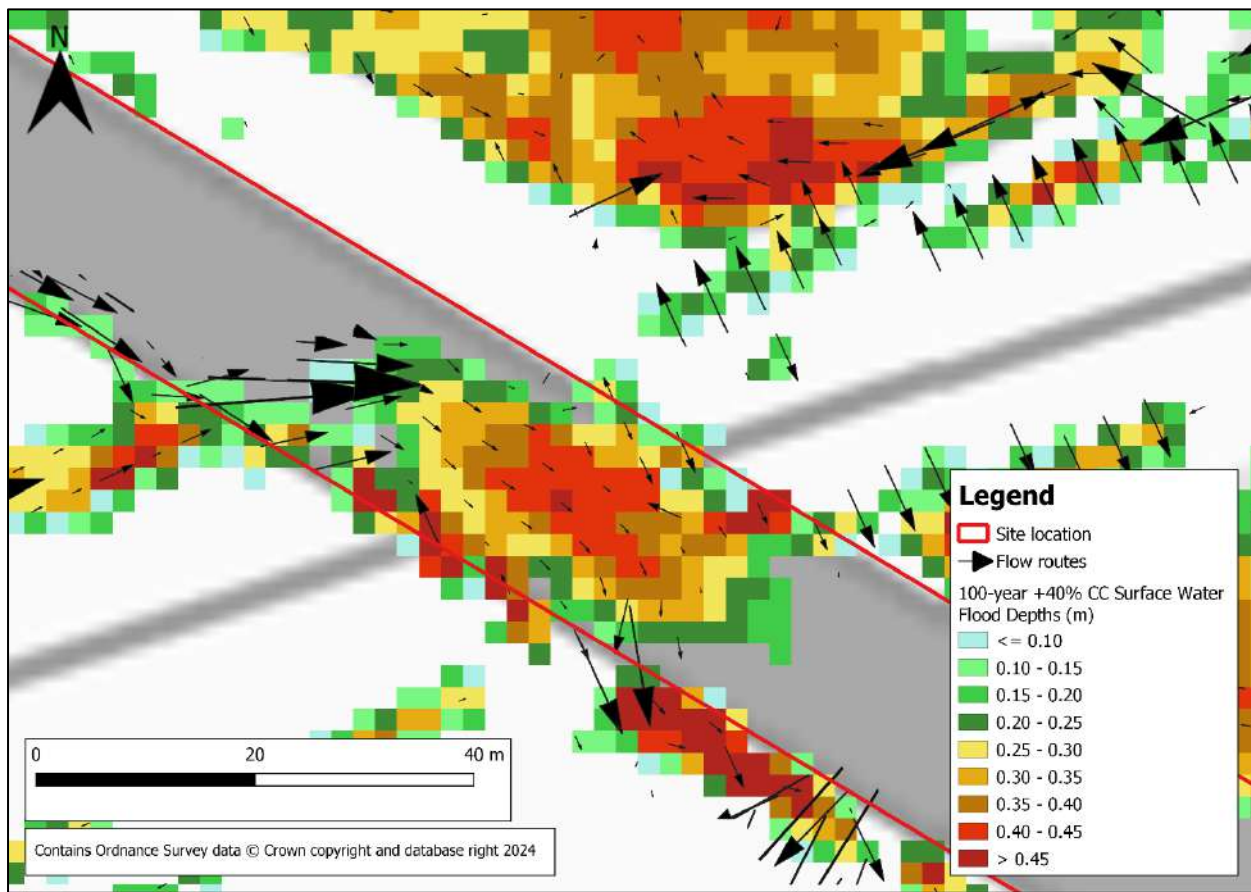


Figure 3-9: 100-year plus 40% climate change surface water flood depths (enlarged)

Figure 3-8 and Figure 3-9 indicate flood depths of between 0.08m and 0.45m are predicted during the 100-year plus 40% climate change event beneath the railway bridge along the A5. Flood depths on third party land to the north of the A5 reach a maximum of 0.51m. The arrows, which denote the direction of overland flow, confirm that water is not conveyed along the A5 beneath the railway bridge.

3.2.2 Peak modelled flood levels

The peak modelled flood levels during the 100-year plus 40% climate change surface water flood event are shown in Figure 3-10.

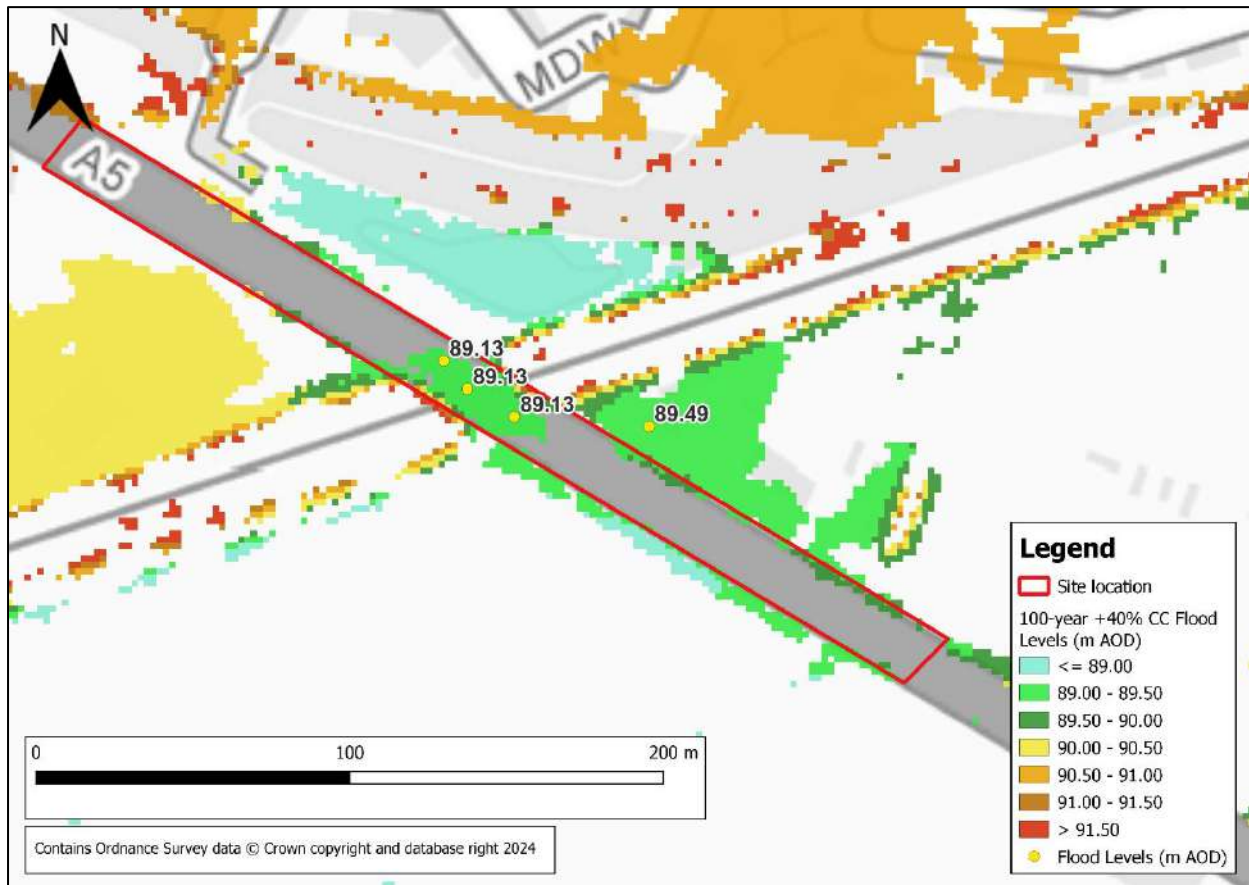


Figure 3-10: 100-year plus 40% climate change surface water flood levels

Figure 3-10 shows that the 100-year plus 40% climate change surface water flood level reaches a maximum of 89.13m AOD beneath the railway bridge along the A5.

3.2.3 Hazard-to-people classification

The surface water hazard-to-people classification during the 100-year plus 40% climate change event has been mapped using the formula as suggested in Defra's FD2321/TR2 "Flood Risk to People". The different hazard categories are shown in Table 3-1 and the Hazard Classification at the site during the 100-year plus 40% climate change surface water event is shown in Figure 3-11.

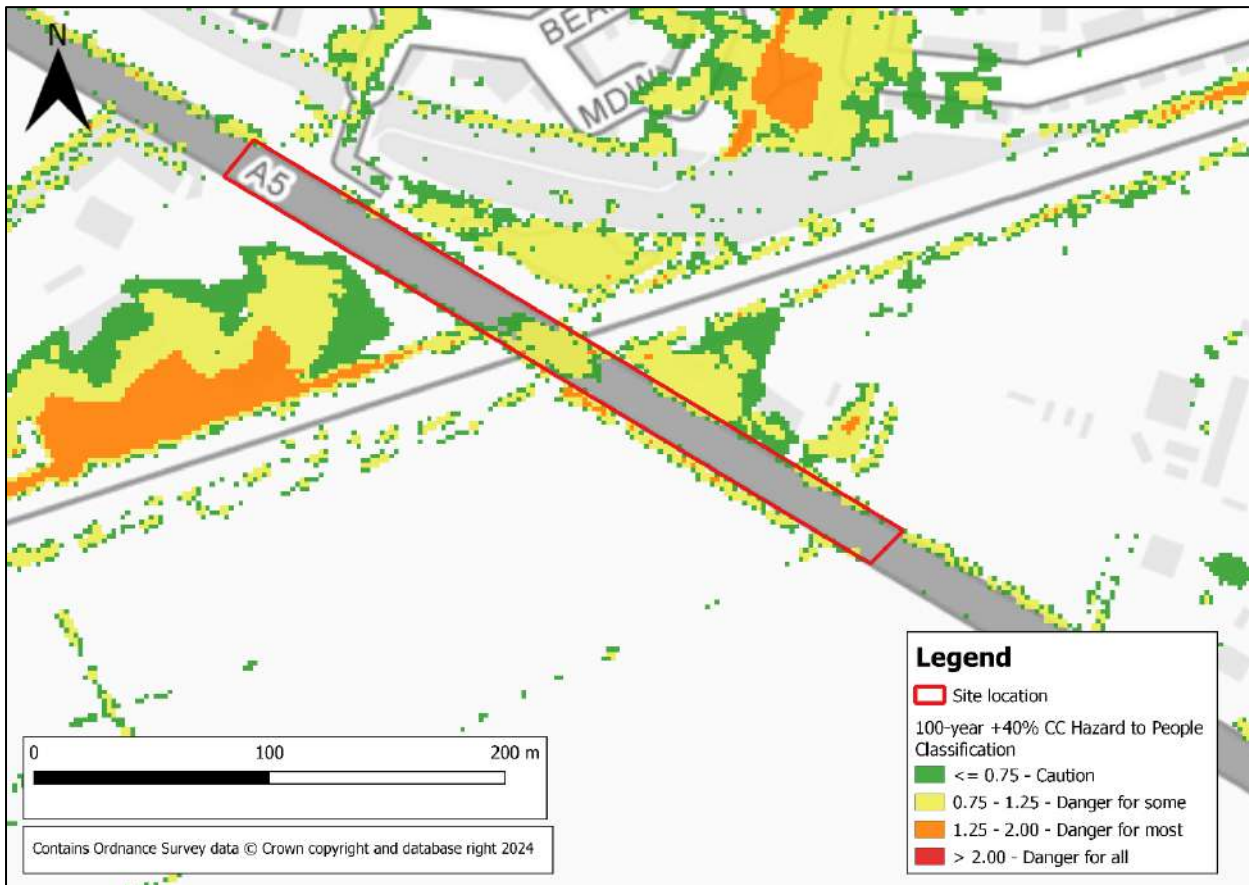


Figure 3-11: 100-year plus 40% climate change surface water Hazard-to-People Classification

Figure 3-11 shows that during the 100-year plus 40% climate change surface water flood event the hazard rating ranges from 'caution' to 'danger for some' along the A5 at the site. There are small, isolated cells of 'danger for most' along this stretch of the A5, however, these are minimal.

4 Post Development Model Results

4.1 Post development scenario

The post development scenario involves the minor lowering of the A5 carriageway where the road crosses beneath the railway bridge. As the site is not affected by flooding during any of the modelled fluvial flood events, it was not necessary to model the fluvial post development scenario. This section is therefore focused on the surface water post development scenario.

4.2 Modelled flood extent

The modelled surface water flood extent during the post development 100-year plus 40% climate change flood event is shown in Figure 4-1.

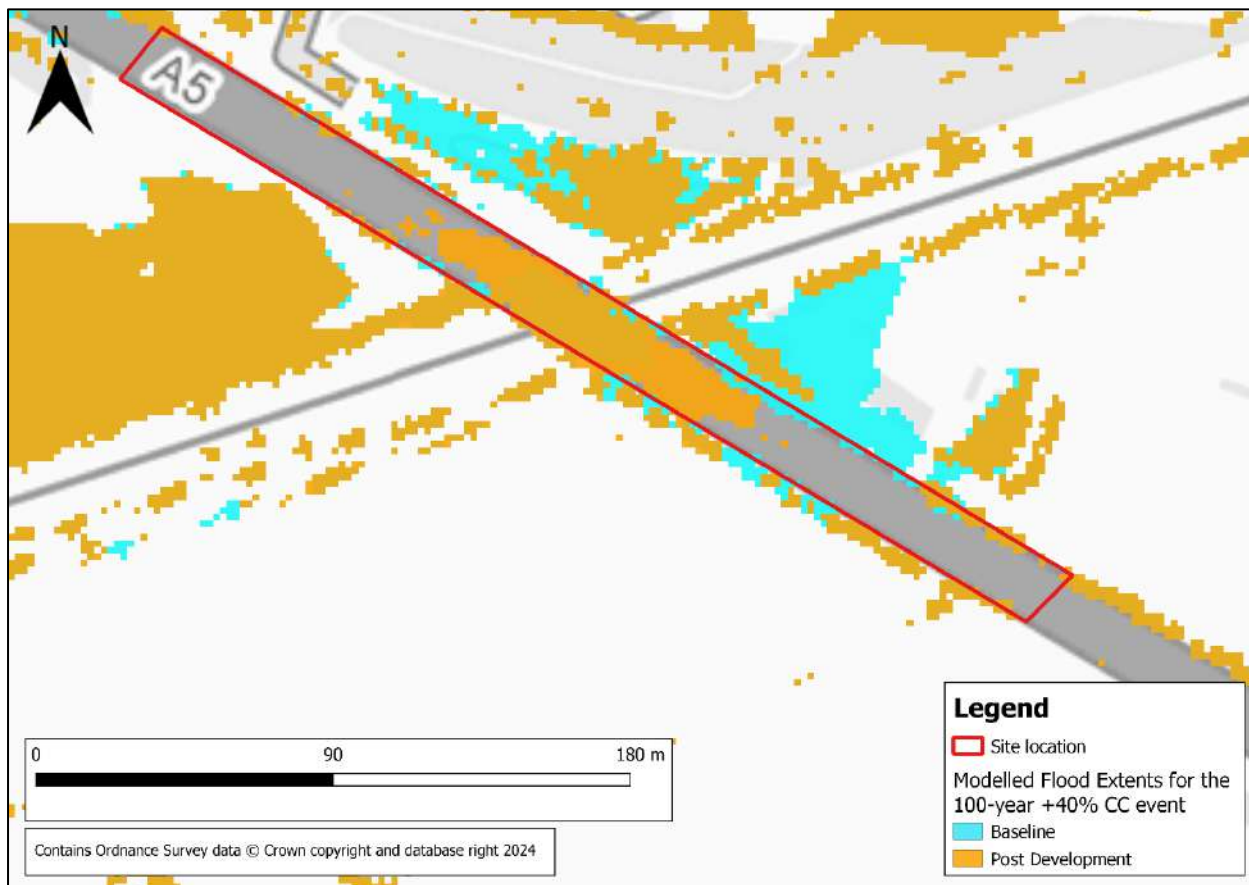


Figure 4-1: Post development surface water flood extent for 100-year plus 40% climate change

The lowering of the carriageway is predicted to extend flooding further along the A5 compared to the baseline scenario by approximately 26m in the north-westerly direction and 38m in the south-easterly direction. However, the changes in road level do not increase flood risk across third party land to the north and south of the carriageway.

4.3 Depth impact analysis

Figure 4-2 shows the difference in the flood depth for the baseline and post development scenario during the 100-year plus 40% climate change surface water flood event.

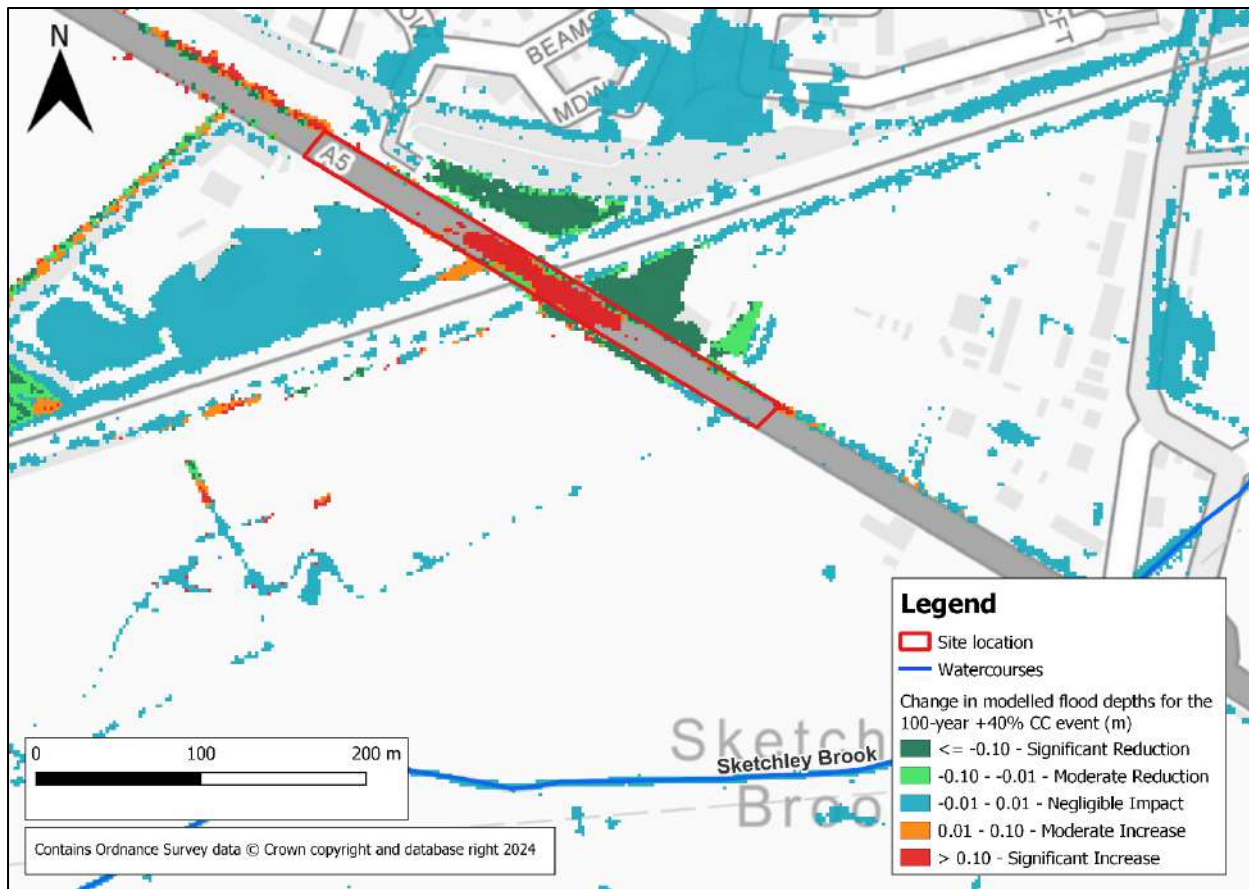


Figure 4-2: Depth impact analysis on the baseline 100-year plus 40% climate change and post development flood depths

Figure 4-2 shows there is an increase in flood depths of approximately 0.32m along the section of the A5 where the proposed lowering of the carriageway is to take place. There is also a decrease in flood depths of approximately 0.11m to land adjacent to the A5 to the north, showing third party land will not be impacted by these proposed works. There are also small, isolated areas along the A5 outside the site boundary which show increases in flood depths between 0.01m - 0.1m, or greater than 0.1m. These are due to model instabilities when filtering the surface water extents, and therefore do not accurately represent the potential change in flood depth post development.

4.4 Post development flood levels

Figure 4-3 shows the flood levels at and around the site when the post development scenario is applied to the model.

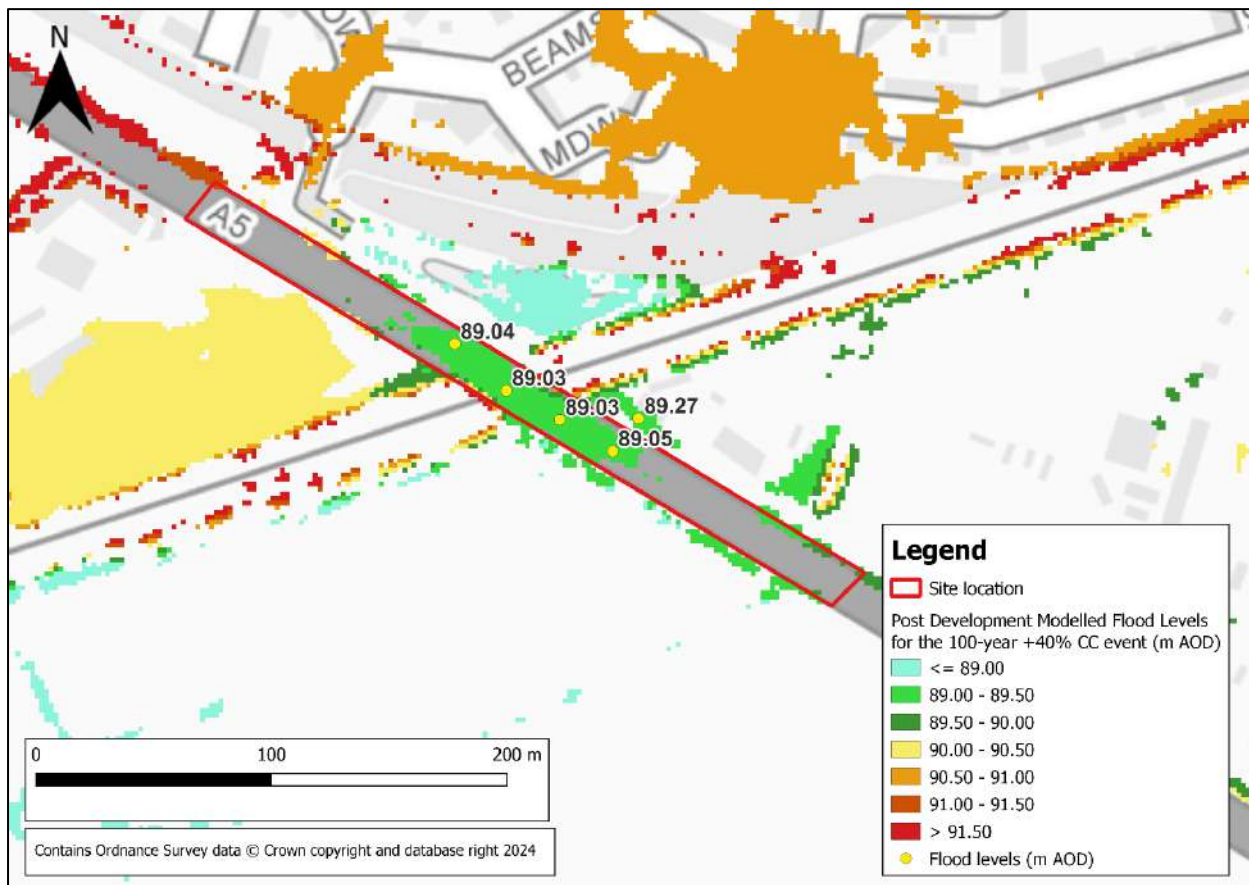


Figure 4-3: Post development scenario flood levels for the 100-year plus 40% climate change

Figure 4-3 shows that the peak flood level along the A5 at the site reduces by approximately 0.09m after road levels have been lowered. The maximum flood level during the post development 100-year plus 40% climate change surface water flood event is 89.04m AOD beneath the railway bridge along the A5. Flood levels to the north of the A5 on third party land also reduces by approximately 0.22m post development to 89.27m AOD.

4.5 Post development hazard to people classification

The surface water hazard-to-people classification during the post development 100-year plus 40% climate change event has been mapped using the formula as suggested in Defra's FD2321/TR2 "Flood Risk to People". The different hazard categories are shown in Table 3-1 and the Hazard Classification at the site during the post development 100-year plus 40% climate change surface water event is shown in Figure 4-4.

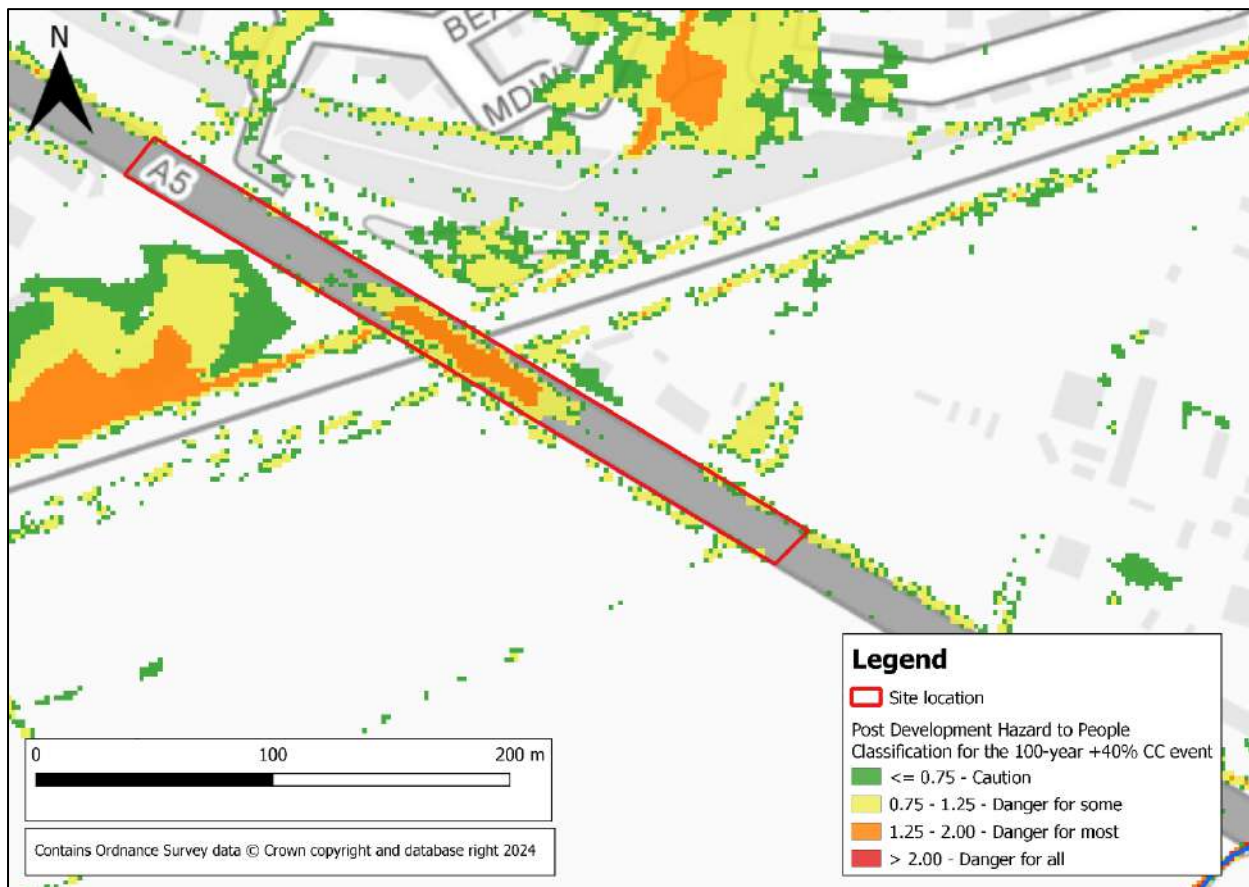


Figure 4-4: Post development scenario 100-year plus 40% climate change surface water Hazard-to-People Classification

Figure 4-4 shows that during the post development 100-year plus 40% climate change surface water flood event the hazard rating ranges from 'caution' to 'danger for most' along the A5 at the site. The hazard rating across third party land to the south and north of this section of the A5 ranges from 'caution' to 'danger for some'.

5 Conclusion and Recommendations

5.1 Conclusion

- JBA Consulting (JBA) were commissioned by ADC Infrastructure Ltd to undertake a fluvial and surface water hydraulic modelling study of the Sketchley Brook to inform a highway improvement scheme along a section of the A5 in Hinckley, Leicestershire. The Sketchley Brook is located to the south of the section of the A5 (Watling Street) where highway improvements are due to take place.
- The purpose of the study is to increase the understanding of the fluvial and surface water flood risk at the site and to surrounding third party land. To achieve this a 1D-2D Flood Modeller-TUFLOW hydraulic model of the watercourse and floodplain was obtained from the Environment Agency and updated to allow accurate representation of flood levels, extents, velocities and hazard to people.
- The proposal is to improve sections of the A5 in Hinckley. The potential highway works comprise minor lowering of the carriageway where the A5 crosses beneath a railway bridge.
- The lowering of the carriageway location, hereafter referred to as 'the site', is situated at its closest point, approximately 245m north of the Sketchley Brook. To the east of the site, the Sketchley Brook meanders frequently but generally flows in a south-westerly direction before flowing into the River Anker approximately 2.3km south-west of the site. The Ashby de la Zouch canal crosses the Sketchley Brook approximately 695m east of the site.
- A 1D-2D hydraulic model was developed using the Flood Modeller-TUFLOW modelling packages. The model extent includes the site and the Sketchley Brook to the south and east of the site in order to refine the understanding of flood mechanisms.
- The fluvial hydraulic model was simulated for the 30-year (3.3% AEP), 100-year (1% AEP) and 1000-year (0.1% AEP) fluvial events. Additionally, a 100-year plus 30% allowance for climate change (CC) event was simulated in line with the latest Environment Agency guidance for the higher central allowance in the 2080's epoch. The higher central allowance was used in this study due to the site being deemed as essential infrastructure.
- The surface water hydraulic model was simulated for the 30-year, 100-year and 1000-year surface water events. Additionally, a 100-year plus 40% allowance for climate change event was simulated in line with the latest Environment Agency guidance for the upper end allowance in the 2070's epoch. A one-hour critical storm duration was used when simulating these events as it produced the highest flood depths compared to the three and six-hour storm durations.
- A review into the model's sensitivity to changes in flow, roughness and downstream boundary parameters has been undertaken. The fluvial model is sensitive to increases in flow but is not sensitive to increases in roughness and

downstream boundary conditions. The surface water model is not sensitive to increases in flow and roughness.

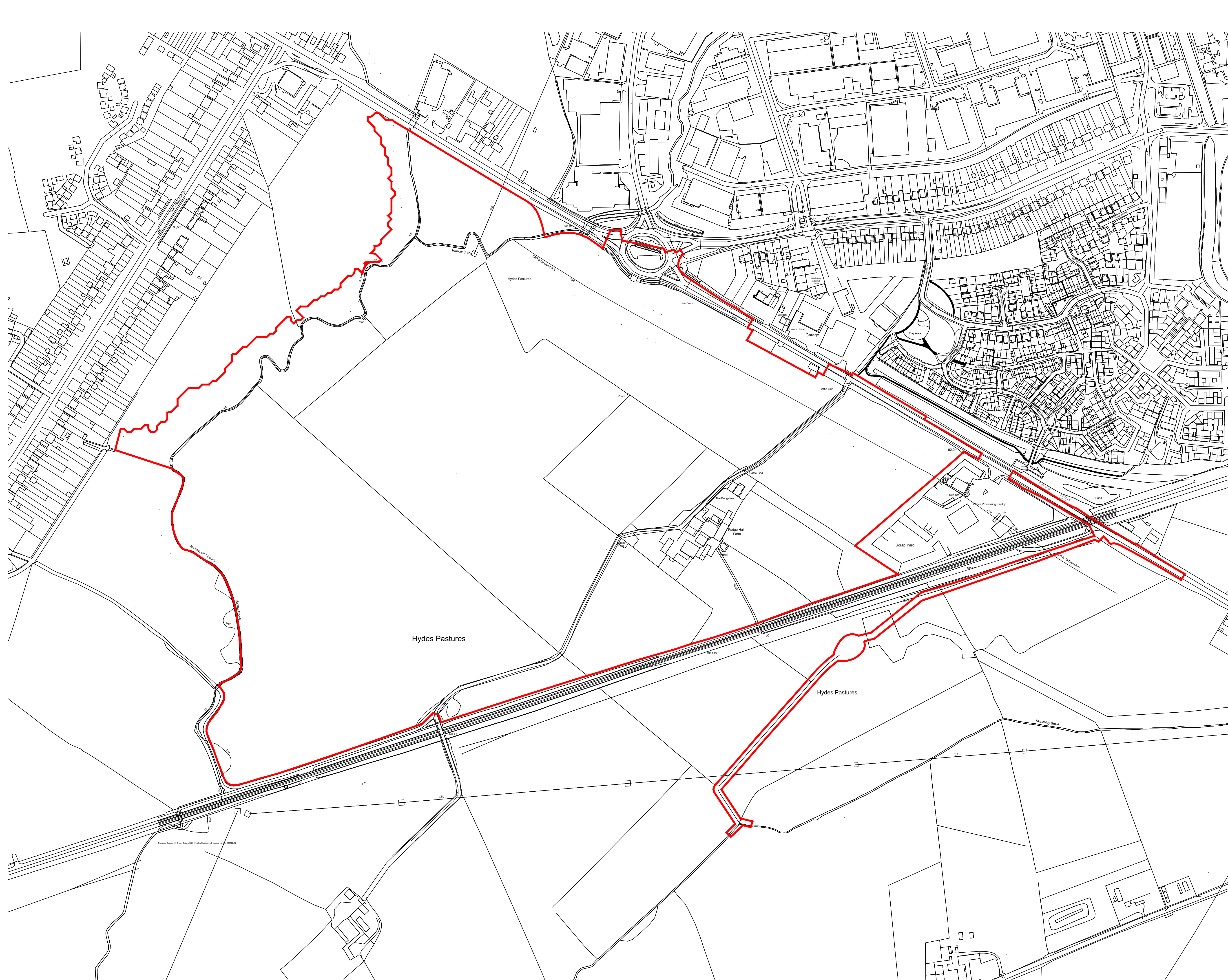
- Baseline model results indicate that:
 - The site is outside of the 30-year, 100-year, 100-year plus 30% CC, and 1000-year modelled fluvial extents.
 - The site experiences flooding during the 30-year, 100-year, 100-year plus 40% CC, and 1000-year modelled surface water events.
 - During the modelled 100-year plus 40% CC surface water event, peak flood levels reach 89.13m AOD along the A5 beneath the railway bridge.
 - During the modelled 100-year plus 40% CC surface water event, the hazard rating at the site is predicted to range from 'caution' to 'danger for some'. There are small, isolated areas of 'danger for most' along this stretch of the A5, however, these are minimal.
- A post development scenario was run for the 100-year plus 40% climate change surface water event to evaluate flood risk as a result of the proposed development, including proposed mitigation. As no fluvial flooding is predicted at the site during all modelled fluvial flood events, it was not necessary to simulate a post development fluvial scenario. In this study, the post development involved the lowering of the A5 carriageway beneath the railway bridge. During the post development design surface water flood event, the detailed hydraulic modelling results show:
 - Flooding will extend further along the A5 compared to the baseline scenario by approximately 26m in the north-westerly direction and 38m in the south-easterly direction. However, the changes in road level do not increase flood risk across third party land to the north and south of the carriageway.
 - There is an increase in flood depths of approximately 0.32m along the section of the A5 where the proposed lowering of the carriageway is to take place. There is also a decrease in flood depths of approximately 0.11m to land adjacent to the A5 to the north, showing third party land will not be detrimentally impacted by these proposed works.
- The increase in flood depth during the post development scenario is expected. This is due to:
 - the lowering of the carriageway taking place at an existing low point and;
 - the baseline and proposed surface water modelling scenarios not taking account of the highway drainage proposal that serves to drain surface water in the vicinity of the carriageway beneath the railway bridge. This will be assessed separately by ADC Infrastructure Ltd.

5.2 Recommendations

- It is recommended to validate results from this hydraulic modelling study with the Environment Agency as part of the planning process. The hydraulic modelling

results should be used to inform a site-specific Flood Risk Assessment (FRA) for the site.

A Site Layout



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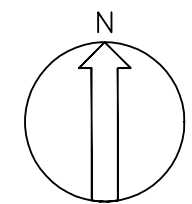
THIS IS A PRELIMINARY FEASIBILITY STUDY ONLY AND IS INTENDED TO BROADLY ASSESS THE VIABILITY OF THE SCHEME.

THE LAYOUT IS BASED ON VARIOUS SOURCES. THE ACCURACY OF WHICH CANNOT BE GUARANTEED AND AS SUCH ALL PROPOSALS ARE SUBJECT TO CONFIRMATION FOLLOWING DETAILED TOPOGRAPHICAL, BUILDING AND OTHER RELEVANT SURVEYS.

IT HAS BEEN ASSUMED THAT OTHER THAN WHERE SHOWN THE SITE IS ESSENTIALLY FLAT WITH NO EASEMENTS TO ABOVE OR BELOW GROUND SERVICES.

WHILST EVERY EFFORT IS MADE TO ENSURE THAT ALL PROPOSALS MEET CURRENT BUILDING REGULATIONS, RELEVANT LEGISLATION AND OTHER GOOD BUILDING PRACTICE, THEY ARE SUBJECT TO CONFIRMATION FOLLOWING LIAISONS WITH RELEVANT LOCAL AUTHORITIES AND OTHER DUE DILIGENCE .

WHERE BOUNDARIES ARE SHOWN THESE ARE AS ADVISED BY THE CLIENT AND ARE FOR GENERAL GUIDANCE ONLY. WHILST PLOTTED WITH REFERENCE TO LAND REGISTRY DATA WHERE AVAILABLE AND INTERPOLATED AS PHYSICAL FEATURES ON SITE WHERE POSSIBLE, THEY ARE NOT INTENDED TO REPRESENT DEFINITIVE SITE EXTENTS OR LEGAL OWNERSHIP.



PLANNING APPLICATION BOUNDARY (EDGED RED)
APPROX. 63.86 HA (157.80 ACRES)

Revision: Date: By:
Client:
AGRARIAN DEVELOPMENT HOLDINGS LTD

Project:
**PROPOSED DEVELOPMENT OFF
WATLING STREET (A5)
HINCKLEY
LEICESTER LE10**

Drawing Title:
SITE LOCATION PLAN



CHARTERED ARCHITECTS & DEVELOPMENT CONSULTANTS

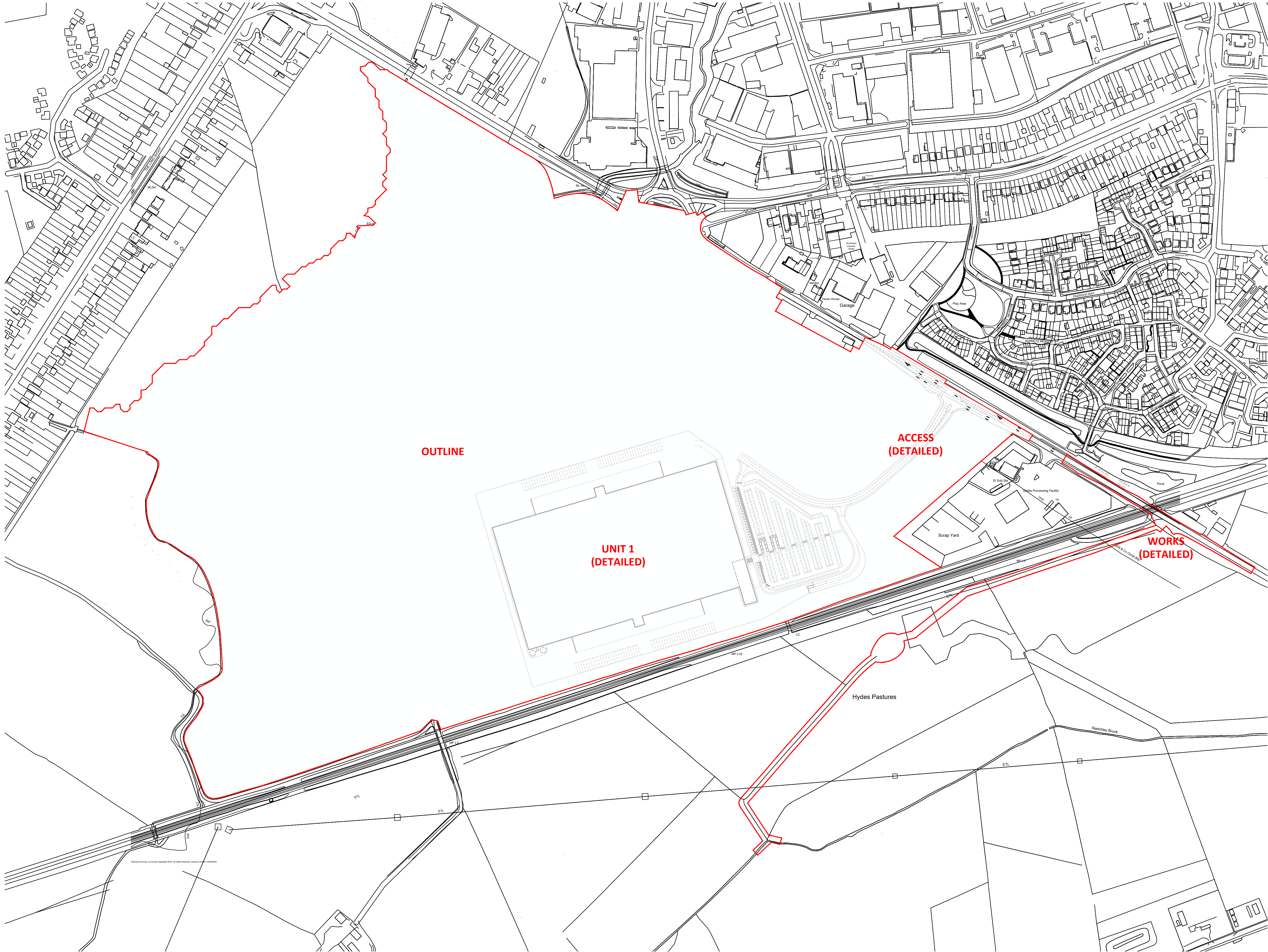
DFC ARCHITECTURE LTD
STIRLING PLACE
40 STIRLING SQUARE
BIRMINGHAM, B3 1TQ

TELEPHONE: 0121 314 2452

Scale @ A1: Date: Design: Draft:
1:2500 AUG 2021 DFC JAC

Drawing Status:
PRELIMINARY PLANNING

Job No: Drawing No: Revision:
18-144 PP-01 L



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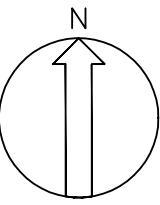
THIS IS A PRELIMINARY FEASIBILITY STUDY ONLY AND IS INTENDED TO BROADLY ASSESS THE VIABILITY OF THE SCHEME.

THE LAYOUT IS BASED ON VARIOUS SOURCES. THE ACCURACY OF WHICH CANNOT BE GUARANTEED AND AS SUCH ALL PROPOSALS ARE SUBJECT TO CONFIRMATION FOLLOWING DETAILED TOPOGRAPHICAL, BUILDING AND OTHER RELEVANT SURVEYS.

IT HAS BEEN ASSUMED THAT OTHER THAN WHERE SHOWN THE SITE IS ESSENTIALLY FLAT WITH NO EASEMENTS TO ABOVE OR BELOW GROUND SERVICES.

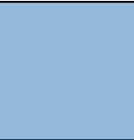
WHILST EVERY EFFORT IS MADE TO ENSURE THAT ALL PROPOSALS MEET CURRENT BUILDING REGULATIONS, RELEVANT LEGISLATION AND OTHER GOOD BUILDING PRACTICE, THEY ARE SUBJECT TO CONFIRMATION FOLLOWING LIAISONS WITH RELEVANT LOCAL AUTHORITIES AND OTHER DUE DILIGENCE .

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EXTENT OF APPLICATION SEEKING
DETAILED PLANNING CONSENT
SITE AREA: APPROX. 13.93 HECTARES



EXTENT OF APPLICATION SEEKING
OUTLINE PLANNING CONSENT
SITE AREA: APPROX. 49.90 HECTARES

Revision: Date: By:

Client:



Project:
PROPOSED DEVELOPMENT OFF
WATLING STREET (A5)
HINCKLEY
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Environment Agency

Stour and Hinckley Flood Mapping

Harrow and Sketchley Brooks Model Report

Final



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Final

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CONTENTS

1	Executive Summary.....	1
2	Introduction	2
2.1	Project Appointment	2
2.2	Study Location	2
2.3	Aims and Objectives	2
3	Understanding Local Flood Risk	3
3.1	Catchment Descriptions (Source)	3
3.2	Watercourse & Floodplain Description (Pathway)	3
4	Modelling Approach and Data Plan	6
4.1	Modelling Approach	6
4.2	Available Data	6
5	Technical Methodology.....	8
5.1	Introduction	8
5.2	Software Versions	8
5.3	Model Geometry	8
5.4	Model Boundaries.....	15
5.5	Model Run Parameters.....	18
5.6	Audit Trail	18
6	Technical Methodology – Map Production	19
7	Model Proving.....	20
7.1	Run Performance	20
7.2	Model Calibration and Validation	20
7.3	Model Sensitivity.....	20
8	Model Results	24
8.1	Design Simulations	24
8.2	Results Discussion	24
8.3	Standard of Protection	25
8.4	Areas Benefitting from Defences	26
8.5	Brodict Road FSA High Level Ecological Review	27
9	Limitations and Future Use	30
9.1	Limitations	30
9.2	Future Uses	30
10	Conclusions	31
11	Recommendations.....	32

Appendices

- Appendix A1
- 1D Structures
- Appendix A2
- Hydraulic Model Schematics
- Appendix B
- Hydrological Report
- Appendix C
- Sensitivity Analysis
- Appendix D
- Hydraulic Model Files and Documentation
- Appendix E
- Mapped Outputs

1 Executive Summary

An ISIS-TUFLOW model of the Harrow and Sketchley Brooks in Hinckley, Leicestershire has been built and run in order to improve understanding of flood risk on the brooks.

The Harrow Brook drains the western part of Hinckley and the Sketchley Brook drains a smaller area to the south. The Sketchley Brook joins the Harrow Brook west of the town and together flow south to join the River Anker.

A new development on the Sketchley Brook is currently under construction; this will result in day lighting of the old culvert and alteration of ground levels in the floodplain.

Predicted flooding for design events up to and including the 0.1% AEP is predominantly within undeveloped areas. Key areas where properties are at risk are East Close, Bridge Road, at the junction of Brookside / Holt Road and at Nutt's Lane. These are all located in the upper and middle reaches of the Sketchley Brook.

Predicted flood extents are not overly sensitive to changes in roughness or downstream boundary conditions. However the elevation of the Ashby Canal embankment as it crosses the Sketchley Brook and the overflow rate from the canal into the brook do influence the flood extents and therefore additional data is required to improve confidence in modelled outputs.

Two formal defences are included in the model; the Brodick Road Flood Storage Area (FSA) and the Longshoot flood wall. These afford a Standard of Protection (SoP) of 0.5% AEP and 0.1% AEP respectively.

Removal of the defences does not place any additional properties at risk in either the 0.1% AEP or 1% AEP. Minor changes in flood extents within existing open space are observed.

A high level assessment of the potential ecological value of the Brodick Road FSA found that re-naturalisation of the area has occurred. Given the apparently limited flood protection use that the FSA has, it may be possible to develop this value further in future.

2 Introduction

2.1 Project Appointment

Hyder Consulting Limited (Hyder) was appointed in May 2012 by the Environment Agency, Midlands Region to undertake a flood risk modelling and mapping study of three River Stour tributaries in Stourbridge, West Midlands and two tributaries of the River Anker in Hinckley, Leicestershire.

This report provides details of the approach taken and the findings of the study for the Harrow and Sketchley Brooks. It is accompanied by other study deliverables, which include: hydraulic models, flood extents, new channel survey and National Flood and Coastal Defence Database (NFCDD) outputs.

2.2 Study Location

The Harrow Brook forms the lower reach of the Battling Brook; together they drain the south western area of Hinckley in Leicestershire. The Sketchley Brook drains a smaller area on the southern edge of Hinckley. Both brooks flow south-west to their confluence just upstream of the River Anker.

2.3 Aims and Objectives

A detailed description of the study requirements was set out in the 'Statement of Requirements (SoR)' supplied by the Environment Agency. The brief confirmed that at present no detailed flood risk information exists for the study area. The overall aim of the study is therefore to ***improve the understanding of flood risk on the Harrow and Sketchley Brooks***, by constructing a 1D-2D linked ISIS-TUFLOW hydraulic model of the watercourses.

In order to meet the study aims, the following objectives were identified:

- Undertake a hydrological assessment to determine flows for the following events: 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1.3% AEP, 1% AEP (with and without climate change), 0.5% AEP and 0.1% AEP.
- Provide model results for all the events list above, with defences present
- Provide model results for the 1% AEP and 0.1% AEP events assuming all defences are removed
- Provide flood extent outlines for all events
- Provide flood depth, flow, stage and hazard grids for all events
- Make an assessment of Areas Benefitting from Defences (ABD)
- Determine the Standard of Protection (SoP) for the Long Shoot Flood Wall and the Brodick Road Flood Storage Area (FSA)
- Improve the understanding of the structures that may have a significant impact on flood risk under normal flow and blockage conditions

3 Understanding Local Flood Risk

This section provides a brief introduction to the study watercourses using the Source > Pathway > Receptor approach to categorising flood risk. The information presented in this section was used as the basis for model schematisation and design.

3.1 Catchment Descriptions (Source)

The Harrow Brook is the name given to the lower reach (downstream of the Ashby de la Zouch Canal) of the Battling Brook. The Battling Brook is fed by surface water sewers draining the Hollycroft area of Hinckley. Upstream of the canal, the contributing catchment is urban however the lower reaches are rural.

The Sketchley Brook is fed by surface water sewers draining the Sketchley Hill area of Hinckley; this contributing catchment is wholly urban. The catchment downstream of the canal is rural.

A detailed description of the catchment characteristics is provided in the Final Hydrology Report.

3.2 Watercourse & Floodplain Description (Pathway)

Figure 3-1 shows the modelled reach of the Harrow and Sketchley Brooks.

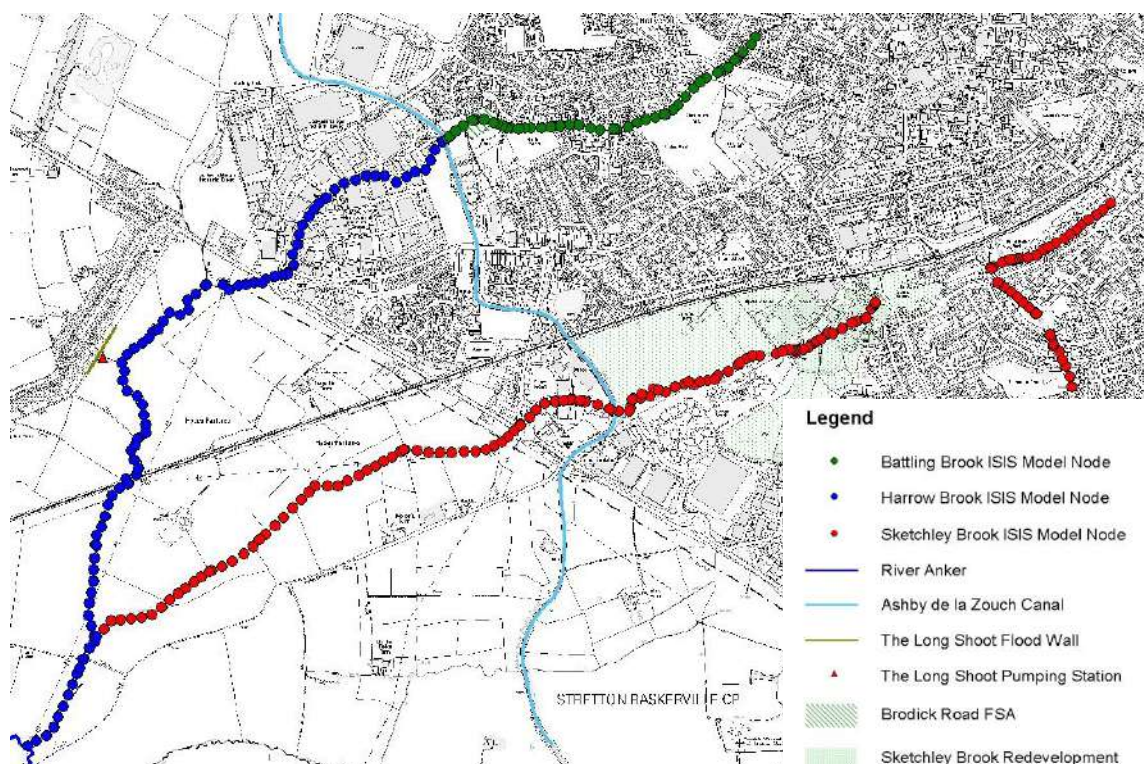


Figure 3-1 Harrow and Sketchley Brooks Model Reaches

The Battling Brook emerges from a culvert at Orkney Close and flows south west through Clarendon Park to Brodick Road. Downstream of Brodick Road, an FSA is in operation with pass forward flows controlled by a narrow weir structure. A box culvert conveys the Battling Brook beneath the Ashby Canal where it becomes the Harrow Brook. The brook flows through the Harrowbrook Industrial Estate and under the A5 to leave the urban area, entering farmland east of The Long Shoot. A flood wall has been constructed behind properties on The Long Shoot, in combination with a pumping station. The brook then changes direction and flows

south, under the railway line to the Sketchley Brook confluence. Some 500 m beyond this, the Harrow Brook flows into the River Anker.

The Sketchley Brook originates from the urban area of Burbage south east of Hinckley centre. There are two tributaries of the Sketchley Brook in its upper reaches. The main watercourse issues from a culvert under allotment gardens on Brookside Road, before flowing through a storage area to enter a long culvert upstream of Bridge Road. A tributary, which flows through two recreation grounds and under Featherstone Drive, Holt road and Brookside, joins from the south, immediately upstream of the long culvert.

Downstream of Rugby Road, the original line of the watercourse was culverted beneath an industrial area; however the current Sketchley Brook development scheme will see the Sketchley Brook day-lighted and re-aligned through this area. At the time of this study, this process was underway although completion is believed to be some time away (Figure 3-2).



Figure 3-2 Sketchley Brook Development, January 2013

Downstream of the development area, a circular brick siphon conveys the Sketchley Brook beneath the Ashby Canal and an overflow weir also allows flow from the canal to enter the brook. After flowing through an industrial park and under the A5, the Sketchley Brook flows south west across farmland to join the Harrow Brook.

3.2.1 Flooding Receptors

The SFRA¹ notes flooding on Rugby Road (predominantly surface water) and Coventry Road. Reports in the Hinckley Times describe surface water flooding in the town centre, Leisure Centre, bus station, Brunel Road, Hill Street and The Borough.

Hinckley has a typical range of residential properties and associated infrastructure, with notable industrial developments located close to the watercourses. The A5 (Watling Street) Trunk Road crosses both Harrow and Sketchley Brooks with the B4109 (Rugby Road) also crossing Sketchley Brook. The regional rail route linking Birmingham and Leicester runs close to the Sketchley Brook and crosses the Harrow Brook. The Ashby de la Zouch Canal crosses both

¹ JBA (2007) Hinckley and Bosworth Borough Council, Blaby District Council, Oadby and Wigston Borough Council Joint Strategic Flood Risk Assessment

watercourses. There is a sewage works located on the left bank of the Sketchley Brook in the reach upstream of the canal crossing.

4 Modelling Approach and Data Plan

4.1 Modelling Approach

Based upon the study brief, available data (see Table 4-1) and resulting aims and objectives, a linked 1D-2D linked hydraulic modelling approach has been applied. It was deemed that this approach is appropriate as it would:

- Define out of bank flow paths
- Account for floodplain storage and conveyance
- Determine any transfer of flows into and out of the river channel via overland flow routes
- Remove uncertainty from the mapping of flood outlines for design events.

The 1D-2D linked approach offers the most appropriate level of accuracy for a project of this nature. The use of ISIS 1D for the channel enables a good representation of the river channel and structures to be made. Linking the 1D channel to a 2D TUFLOW domain allows for a far more accurate flood outline to be produced, compared to mapping of 1D only model output. This is particularly relevant for modelling the complexity of overland flow routes once water is out of bank.

4.2 Available Data

Table 4-1 summarises the information that was made available for this study, and provides an assessment of the quality and suitability of that data for use within this study.

Description	Data Type	Source/Author	Dates	Data Quality
Ordnance Survey 10K tiles	GIS	Environment Agency/OS	June 2012 (received)	Good quality
Ordnance Survey 50K tiles	GIS	Environment Agency/OS	June 2012 (received)	Good quality
Ordnance Survey Mastermap tiles	GIS	Environment Agency/OS	June 2012 (received)	Good quality
Main River Lines	GIS	Environment Agency	June 2012 (received)	Good quality
Flood Zone Shapefiles	GIS	Environment Agency	June 2012 (received)	Variable, Sketchley Brook outlines do not align with topography
LiDAR data	ASCII	Environment Agency Geomatics	June 2012 (received)	Good resolution (2 m), quality is generally good
Sketchley Brook Development FRA	ISIS Model and Report	BWB Consulting	June 2012 (received)	Good Quality
River Anker Model	ISIS Model	Halcrow	June 2012 (received)	Results files were incomplete

Description	Data Type	Source/Author	Dates	Data Quality
River Anker NFCDD Extract	GIS	Environment Agency	Received October 2012	Good, peak stage for range of design events
Photographs from site visits undertaken by Hyder Consulting	JPEG	Hyder Consulting	4 th July 2012 / 29 th January 2013 (taken)	Good quality
River channel survey data	AutoCAD	Environment Agency	March 2012	Good
Asset information from Canal and River Trust	Email	Canal and River Trust	Received October 2012	Average. Information is limited
Sketchley Brook Survey Data	AutoCAD	Maltby Land Surveys	Surveyed January 2013	Good quality

Table 4-1 Data Received

4.2.1 Site Visit

Two site visits to Hinckley were undertaken; the first in July 2012 and the second to the upper reaches of Sketchley Brook in January 2013. Where possible, areas at risk of flooding and significant watercourse structures were visited and photographs taken.

4.2.2 Defences

The supplied NFCDD data shows only two raised defences within the study area; one located on the Battling Brook at Brodick Road FSA and one located adjacent to the Harrow Brook at The Long Shoot. The remainder of the watercourses are all classed as 'natural channel'.

Defacto Defences

Defacto defences are structures which have not been specifically built to retain floodwater, are not maintained for this purpose but which may afford some protection against flooding, for example boundary walls, road and rail embankments. The Ashby Canal and the railway line are both constructed such that they would provide a barrier to floodplain flows.

4.2.3 Canal and River Trust

Consultation was carried out with the Canal and River Trust regarding the potential for interaction between the Ashby Canal and the brooks as they flow beneath. This confirmed that there is no interaction between the Harrow Brook and the Ashby Canal. An off-take weir is however in operation on the canal at the Sketchley Brook siphon, discharging flows into the brook. Further information is given in Section 5.4.1.

5 Technical Methodology

5.1 Introduction

This section of the report gives a technical description of the model set up, concentrating on any non-standard procedures that have been adopted during the model build.

The 1D ISIS models have been run in an unsteady state with a fixed timestep, as is required when linking ISIS and TUFLOW.

5.2 Software Versions

The models have been built and run using the following software versions:

- ISIS version 3.6
- TUFLOW version 2012-05-AC-iSP-w32

5.3 Model Geometry

5.3.1 1D Domain - Channel Geometry

Sketchley Brook

An ISIS model of the Sketchley Brook was completed as part of the Flood Risk Assessment (FRA) for the redevelopment. Two versions of the model were supplied; Baseline (pre development) and Proposed (post development). As construction has already commenced on the development, the post development model geometry was used for this study.

The post development model includes the proposed realignment of the Sketchley Brook, the removal of existing culverts and re-profiling of the channel cross section to improve conveyance and flood storage.

The FRA model was 1D ISIS only; therefore all the reservoir and spill units used to model out of bank flows were removed as part of the conversion to an ISIS TUFLOW model. In addition, where bridge springing points were below the corresponding channel section levels, these were corrected to ensure accurate calculation of afflux across the bridge.

The downstream extent of the supplied model was the Ashby Canal; therefore new survey data supplied by the Environment Agency was used to extend the model from this point to the Harrow Brook confluence. The new survey data was also used to improve the existing (FRA model) geometry in the vicinity of the canal.

Upstream of Bridge Road (upstream extent of FRA ISIS model), new survey data collected in January 2013 was used to extend the ISIS model as far as the allotments at Brookside on the main watercourse and Tilton Road on the tributary.

Battling Brook / Harrow Brook

A channel survey was provided and used as the basis for a new ISIS 1D model. In addition to cross-section survey, long-profiles were provided. In some locations long-sections were used to provide additional information on bed levels around structures.

Where surveyed river sections extend into the floodplain (which is to be represented within the 2D TUFLOW domain), sections were truncated in ISIS using deactivation markers. This ensures there is no duplication of conveyance between the 1D and 2D domains.

5.3.2 1D Domain - Channel Roughness

Channel and floodplain roughness values are represented in hydraulic models using the Manning's 'n' coefficient. These have been applied throughout the models with reference to a walkover survey of the reach of the watercourse. Selected values are supported by photographs of the model reach that were provided with the topographical survey. All information was used with reference to Chow's industry standard reference guide to roughness coefficients (1959)².

The majority of the Harrow Brook channel throughout the model reaches may be described as "clean, straight, full stage, no rifts or deep pools". This meets with an advised Manning's n of 0.04. The Sketchley Brook passing through the re-development area has been assigned a roughness value of 0.03 for the in channel sections; this was not changed as part of this study. Downstream of the Ashby Canal, survey photos indicated that the roughness value for the Sketchley Brook should be lower than the Harrow Brook as the channel was more open and free of obstructions; therefore the in channel roughness was set to 0.035.

Out of bank areas on the Harrow Brook (those represented within the 1D ISIS domain) have been assigned a preferred Manning's 'n' value of 0.06. This represents the overhanging vegetation along the channel boundaries for much of the open channel sections. The ISIS out of bank areas for the Sketchley Brook downstream of the Ashby Canal have been lowered to 0.052 as there is less vegetation overhanging the channel.

The sensitivity of the model output and the impact of this upon the conclusions made by this study have been assessed by varying the Manning's values throughout the model reach by $\pm 20\%$ for selected return periods. The outcome of this analysis is discussed in Section 7.3.1 of this report.

5.3.3 1D Domain - Structures

Structures on the Harrow and Sketchley Brooks were modelled using ISIS; a summary table is provided in Appendix A.

5.3.4 2D Domain - Floodplain Geometry

A Digital Terrain Model (DTM) was created from the supplied filtered LiDAR data at 2 m resolution using MapInfo/Vertical Mapper. This is provided as a study deliverable. A TUFLOW topography file (z pt layer) was created with a cell size of 5 m and elevations were assigned to each z pt by sampling the DTM. The grid was orientated at 340 degrees from a north-south line to provide the best fit for the majority of the watercourse.

Floodplain Alterations

A number of alterations are made to the 2d_zpt file each time the model runs. By making these alterations each time the model is run, the model user can easily revert to the LiDAR derived DTM at any time by changing commands in the model geometry file. Table 5-1 summarises these changes.

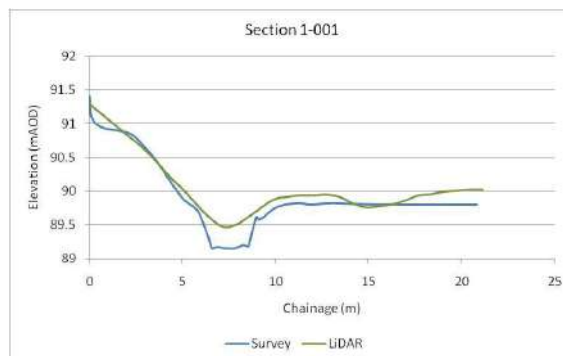
²Chow, V.T. (1959). Open Channel Hydraulics. New York, NY: McGraw-Hill Book

Floodplain alteration	Model file	Scenarios applied
Lowers LiDAR data within Brodick Road FSA as survey data indicated lower levels (see below)	2d_zsh_BrodickRoadFSA_V1.MIF	All scenarios
Enforced height of Longshoot Flood Defence Wall based on elevations in the NFCDD	2d_zln_LongshootWall_V0.mif	All Defended scenarios
Enforces surveyed bank heights using ZP points in the 2d_bc layer	2d_bc_Hinckley_V1.mif	All scenarios
Enforced height of embankment at Brodick Road FSA based on elevations in the NFCDD	2d_zln_BrodickFSAWall_V0.mif	All Defended scenarios
Replaces roads which have been incorrectly filtered out of the LiDAR	2d_zln_ReinstatedRoads_V0.mif	All scenarios
Replaces roads which have been incorrectly filtered out of the LiDAR	2d_zsh_ReinstatedRoads_V0.MIF	All scenarios
Enforcing embankment downstream of Ashby Canal on Harrow Brook	2d_zln_Embankments_V0.mif	All scenarios
Z points for extended model domain into the upstream reaches of Sketchley Brook	2d_zpt_Hinckley_Additional_V2.mid	All scenarios
Enforces surveyed bank heights using ZP points in the 2d_bc layer for extended Sketchley Brook	2d_bc_SketchleyHX_V1.MIF	All scenarios
Smooths over holes in the DTM apparent in filtered LiDAR	2d_zsh_STW_Structures.MIF	All scenarios
Lowers embankment in Brodick Road FSA	2d_zln_BrodickFSAWall_Removed_V0.MIF	Undefended Runs

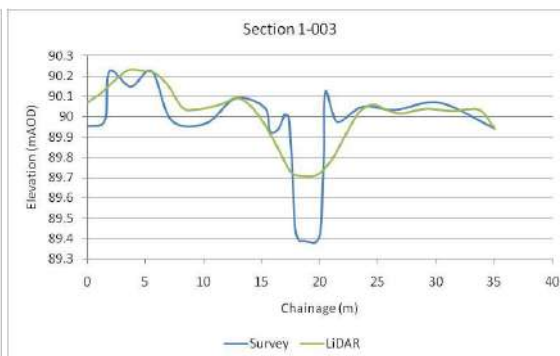
Table 5-1 Floodplain Alterations

Brodict Road FSA

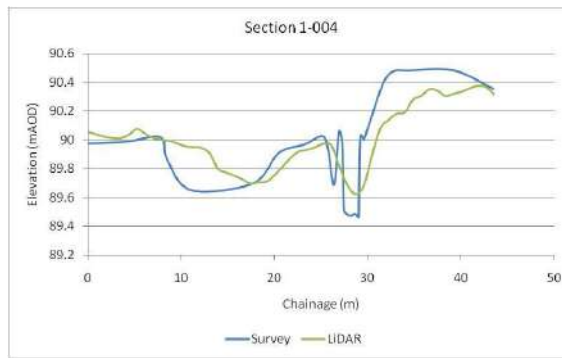
Figures 5-1a to 5-1b show the difference in elevation between the surveyed sections and the LiDAR within the Brodict Road FSA. The SoR states that an estimation of the Standard of Protection (SoP) is required; therefore it was considered necessary to make some adjustments to the LiDAR to improve the definition and resultant increase in storage available.



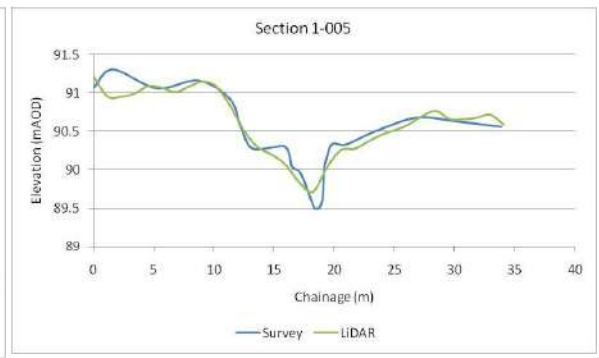
5-1a Section 1-001 (d/s throttle)



5-1b Section 1-003



5-1c Section 1-004



5-1d Section 1-005

A point inspection analysis was carried out to compare each survey point (excluding the ISIS channel) to the LiDAR. This indicated that, on average, the LiDAR was 0.17m higher than the surveyed levels. Consequently a 2d_zsh was applied which lowered all the points within the FSA by 0.17m. The area to which this adjustment was applied was defined by the 91mAOD contour as this was considered to represent the FSA bank top.

The Longshoot Flood Defence Scheme

A flood defence scheme has been installed behind properties 175 to 142 The Longshoot. The scheme comprises a low flood wall and pumping station as shown in Figure 5-2.



Figure 5-2 The Long Shoot Flood Defence Scheme

The flood wall has been enforced in the 2D domain using a 2d_zln file based on the data supplied in the NFCDD.

Additional information was supplied by the Environment Agency which states that the pumping station consists of three identical pumps, each capable of operating at 452.3 l/s (total 1356.9 l/s). An estimate of the catchment flow feeding the small watercourse issuing from behind the properties suggests a peak 0.1% AEP flow of 858 l/s therefore indicating that the

pumping station has sufficient capacity to accommodate design flows up to and including the 0.1% AEP. Further clarification from the Environment Agency MEICA Team stated that the pumping station was design to ensure the capacity could be met should the inflow culvert be improved to allow more water to reach the pumping station. The site is also designed to accept a fourth pump should the calculated flows increase.

No survey data was made available for the Long Shoot watercourse therefore it was not considered appropriate to approximate the channel geometry in this location.

It is therefore concluded at this stage that modelling of the pumping station is unnecessary and that given the lack of detailed channel data to fully define the scheme set up and the magnitude of catchment flows compared to pump capacity could lead to misleading results being presented. It is recommended that if the pumping station is to be included in the model, additional survey data is provided to model the scheme explicitly, including the impact of the culvert under the A47.

Sketchley Brook Redevelopment

The Sketchley Brook redevelopment will result in a change in ground levels from those supplied in the LiDAR data; details of the proposed topography were not available for this study. It is highlighted that results between Rugby Road and the Ashby Canal are viewed with caution and that the model should be updated when this information becomes available.

5.3.5 2D Domain - Floodplain Roughness

Roughness values are assigned using the feature codes contained within the Ordnance Survey (OS) MasterMap layer. Table 5-5 lists the feature codes, their description as set out within the GIS attributes and the Manning's n value to be used.

The OS MasterMap defines general surfaces as "Features representing, describing or limiting areas of land not covered by buildings or structures". Where these codes are assigned 'makes' of manmade and natural, these have been separated and classified differently as shown in Table 5-2 These roughness values were applied consistently across all model simulations by the use of one single TUFLOW *.tmf file.

MasterMap Feature Code	Description	Make	Manning's n	Justification
10021	Building	Manmade	0.5	Higher n value required to simulate resistance to flow
10053	General Surface	Multiple	0.08	Combination of surfaces; 0.08 is a conservative approach to account for surfaces ranging from tracks to woods.
10054	General Surface, Step	Manmade	0.025	Likely to be concrete, asphalt, gravelled. May include railings.
10561 (10056)	General Surface	Natural	0.05	Grass, scrub
10562 (10056)	General Surface	Manmade	0.025	Likely to be concrete, asphalt, gravelled
10062	Building	Manmade	1	High n value required to simulate resistance to flow
10089	Water		0.035	Value for channel bed

MasterMap Feature Code	Description	Make	Manning's n	Justification
10096	Heritage and Antiquities, Land		0.03	For example standing stones, earthworks, hill figures, ruined buildings, tombs; and stone circles. Therefore value for short grass is appropriate given that such features are unlikely to be allowed to become significantly overgrown
10076	Heritage and Antiquities, Land		0.03	
10111	Natural Environment, Coniferous /Non Coniferous Trees	Natural	0.1	Woodlands
10119	Roads, Tracks, Paths	Manmade	0.025	Likely to be concrete, asphalt, gravelled
10123	Roads, Tracks, Paths	Manmade	0.025	Likely to be concrete, asphalt, gravelled
10167	Rail	Manmade	0.05	Large grade stones
11721 (10172)	Roads, Tracks, Paths	Natural	0.025	Private access tracks and drives; more likely to be gravel rather than tarmac
11722 (10172)	Roads, Tracks, Paths	Manmade	0.02	Public Roads, tarmac
10183	Roads, Tracks, Paths (roadside)	Manmade	0.02	Pavements therefore relatively smooth surfaces
10185	Structures	Manmade	1	High n value required to simulate resistance to flow
10217	Land (unclassified)	Unclassified	0.05	Often new developments e.g. residential. Covers buildings and land.

Table 5-2 Floodplain Roughness

As with the 2D topography, MasterMap data used to define the roughness across the Sketchley Brook development site does not reflect the post development situation. This should be updated in future when this information becomes available.

5.3.6 Blockage Assessment

The SoR requests that information is provided to highlight the structures which have the most significant impact on flood risk under both normal flow and blockage conditions. Following review of draft model outputs (0.1% AEP only) an assessment of structures where blockage analysis may prove useful was made with five structures presented in Table 5-3. It was envisaged that some or all of these structures may have been tested for blockage impacts within the model as part of the final model runs, however it is now understood that this testing will take place following completion of the study.

Investigation of blockage at the canal culvert on the Harrow Brook may demonstrate that flooding to previously unaffected residential properties is possible. The effects of a blockage on the equivalent culvert on the Sketchley Brook would also be of interest, though it should be

remembered that final ground levels in the area that would be most affected are currently unknown due to the on-going development.

Blockage of the A47 crossing of Harrow Brook may cause new flooding to industrial premises, though this would be dependent on the severity of the blockage and the design event for which the blockage was simulated.

Blockage of the structures identified on the Sketchley Brook tributary would most likely follow the flooding patterns already seen for the 0.1% AEP design event. This may mean that at less severe design events, properties that would otherwise not be flooded would be at risk due to the blockage.

Following review of design results from higher AEP events, the same five culverts (discussed above) are recommended for consideration of blockages. With the exception of the Harrow Brook canal culvert, the impacts of flooding with clean-running culverts for these less severe events is much less than is expected for the 0.1% AEP, it is therefore recommended that blockages are simulated for a small and medium event (for example, 5% and 1% AEP). For the Harrow Brook canal culvert, it is recommended that a blockage is also simulated for the 0.1% AEP, to investigate whether this might be sufficient to cause overtopping of the canal.

Location	Model Node	Cross-section Area (m ²)	Property levels upstream	Overtopping level	Maximum water level (0.1% AEP)
Harrow Brook Canal culvert	Har1.044u	3.96	91.60	92.40	90.58
Harrow Brook A47 culvert	Har1.033u	4.67	89.90	90.25	89.49
Sketchley Trib Featherston Drive	SKT550	0.77	108.90	108.55	109.06
Sketchley Trib Holt Road	SKT432	1.03	107.80	107.65	107.92
Sketchley Brook Canal Culvert	SKBR_14	1.41	n/a	92.25	92.38

Table 5-3 Potential Blockage Locations

5.3.7 Standard of Protection Assessment

Brodict Road FSA

The SoR stated that an assessment of the standard of protection afforded by the Brodict Road FSA is required. The NFCDD states that the elevation of this raised earth embankment is 91.5 mAOD; these levels have been used to enforce the height of the embankment within the model. In the absence of any apparent flooding to properties downstream of the FSA, the SoP will be defined as the design event at which the FSA embankment overtops.

PO lines have been used to record the flow leaving the FSA over the embankments during the simulation. These flows are indicative of the additional volume required to meet the SoP for each design event. Results from this assessment are presented in Section 8.3.

In addition to the SoP assessment a high level ecological review of the Brodick Road FSA has also been undertaken. This is also provided in Section 8.

The Long Shoot Flood Wall

As part of this study, the SoP for the flood wall can only be defined in relation to flooding from the Harrow Brook; no assessment of the SoP related to flows from the minor watercourse has been made. The SoP is therefore defined as the event on the Harrow Brook at which the wall overtops. Further details are given in Section 8.3.

5.4 Model Boundaries

5.4.1 Inflows

ISIS Catchment Flows

Seven QT inflows were applied to the ISIS model:

- HAR01 is a point inflow which supplies inflows to the upstream extent of the Battling Brook.
- SK01 is a point inflow which supplies inflows to the upstream extent of the Sketchley Brook.
- Dodwell is a point inflow capturing the inflows from the unnamed tributary where it joins the Harrow Brook immediately downstream of the A5
- HAR02 is a lateral inflow which distributes Harrow Brook catchment flows downstream of the Ashby canal using an area weighted approach.
- SK02 is lateral inflow which distributes Sketchley Brook catchment flows downstream of the Ashby canal using an area weighted approach.
- SKT is the inflow to the Sketchley Brook tributary
- AshbyCanal is the inflow from the Ashby Canal overflow (see below)

Further information on the derivation of flows is given in the Hydrology Report.

Ashby Canal

The site visit and consultation with the Canal and River Trust confirmed that an offtake weir is in operation as the Sketchley Brook passes beneath the Ashby Canal, shown in Figure 5-3. The Canal and River Trust state that the weir is a knife edge (angle iron) fixed weir crest, 15.2m long with an unknown crest level. No record of flows over the weir is maintained. There are no locks on the 22 mile long Ashby de la Zouch canal meaning that the potential supply of water from the single, large canal pound could be significant and long-lasting.



Figure 5-3 Ashby Canal Offtake

Flow over the weir enters a 600 mm diameter culvert which drops approximately 1 m to join the Sketchley Brook on the western bank of the canal. A Manning's calculation has been carried out to assess the capacity of the culvert to convey flows from the canal into the Sketchley Brook. Based on site visit observations, it was considered that the baseline model should include the flow giving a depth of 150 mm in the culvert, 0.2 m³/s. A sensitivity test has been carried out with half bore flows, 0.75 m³/s.

5.4.2 Downstream Boundaries

The River Anker forms the downstream boundary for the Harrow Brook. In order to determine the most appropriate event magnitude in the Anker for an event on the Harrow Brook, the AASHTO³ manual joint probability analysis based on catchment areas was used. The ratio of the Anker and Harrow Brook catchments is 1:2; therefore the events listed in Table 5-4 were paired.

³ American Association of State Highway and Transportation Officials (AASHTO) Model Drainage Manual, 1999

Harrow Brook Event	Anker Event	Data Source
20%AEP	20%AEP*	Estimated
10% AEP	10% AEP*	AASHTO Table
5% AEP	5% AEP*	Estimated
2% AEP	2% AEP	Estimated
1% AEP	1% AEP	AASHTO Table
0.5% AEP	0.5% AEP	Estimated
0.1% AEP	0.1% AEP	Estimated

Table 5-4 Catchment Event Pairings for Downstream Boundary (*the lowest available event for the River Anker was the 4% AEP therefore this was applied to lower events)

The downstream boundary has been applied as an HTBDY unit in the ISIS model.

Outputs from the NFCDD were supplied for three nodes on the River Anker and were used to define a spatially and temporally varying stage-time boundary along the river. The stage was set to increase gradually from the ZC point level to the peak stage for each given event starting from minus five hours so that at zero hours the peak stage was applied. This ensures that instabilities do not occur as a result of instantaneously flooding a large number of 2D cells.

5.4.3 Initial Conditions

ISIS initial conditions were generated from running base flows through the model during the model build process.

5.4.4 1D – 2D Links

ISIS

Links between the ISIS channels and the TUFLOW domain have been schematised using HX lines digitised along the channel bank tops. The elevation of the TUFLOW grid square should match, or be close to, the elevation of the bank supplied by ISIS. Therefore, surveyed bank levels were applied to the 2D domain along the HX lines using ZP points in the 2d_bc layer. The levels applied to HX lines have been reviewed in detail, with additional ZP points (elevations taken from LiDAR) added to the 2d_bc layer as necessary. In general all ISIS sections will select two TUFLOW grid cells and consequently supply a water level to the left and right banks independently.

There are two locations where HX lines have not been used:

- Brodick Road FSA: This is due to the high water levels in the FSA submerging the HX lines causing oscillations and model instability. The HX lines have therefore been replaced with a series of spill units linked to SX boundaries which apply a flow to the TUFLOW domain. This has improved model stability.
- Sketchley Brook FSA: A flood storage area is located at the confluence of the Sketchley Brook and Sketchley Tributary. The configuration of the confluence required the use of SX boundaries to stabilise the model as large volumes of flow leaving the channel and entering the FSA submerged the HX lines.

5.5 Model Run Parameters

Table 5-5 summarises the main options and parameters used when running the hydraulic model.

Watercourse	1D Timestep (secs)	2D Timestep (secs)	HTol	QTol	Min ltr	Max ltr	Other Options
Harrow and Sketchley Brooks	1	2	0.01	0.01	2	23	N/A

Table 5-5 Model Run Parameters

5.6 Audit Trail

A modelling tracking spreadsheet has been maintained throughout the model build process and is supplied alongside other digital modelling data. This describes the key differences between each model run, input files, iterations between model versions and comments on model output.

Complete copies of raw model input data, model datafiles, run control files and results have been provided for review alongside this report in Appendix D. This is with the aim of assisting in any review/QA of this study.

6 Technical Methodology – Map Production

Indicative flood extents for the design events will be mapped for the defended and undefended conditions; once approved these derived extents will be used in updating the Environment Agency Flood Zone Maps. The mapping process is described below.

- TUFLOW_to_GIS.exe is used to create a grid of maximum depth (m) from a selected model simulation.
- The depth grid is contoured to provide the flood extent.
- Flood extents for areas modelled in 1D are defined by the ISIS code polygon; this is combined with the 2D depth grid to ensure a continuously wet channel.
- Polygons describing the flood extent are combined in MapInfo *.tab formats for use in mapping. Disconnected areas of flood extent (which can occur as part of the mapping process) have been reviewed and either manually reconnected to the main flood extent (after consultation with the model) or deleted.
- Flood extents are processed using GIS tools to ensure compatibility with the National Flood and Coastal Defence Database (NFCDD).

All outputs have been sensibility checked with reference to available Ordnance Survey mapping and knowledge of the study area. Final mapped extents are provided digitally (in MapInfo *.TAB format) alongside other digital modelling files with this report

7 Model Proving

7.1 Run Performance

7.1.1 Mass Balance

Figure 7-1 shows the combined (1D and 2D) mass balance plot for the 0.1% AEP event. The mass error is higher at the start of the simulation due to a large number of cells on the Anker boundary wetting quickly. Overall the mass balance for this model is acceptable and is not adversely impacting results.

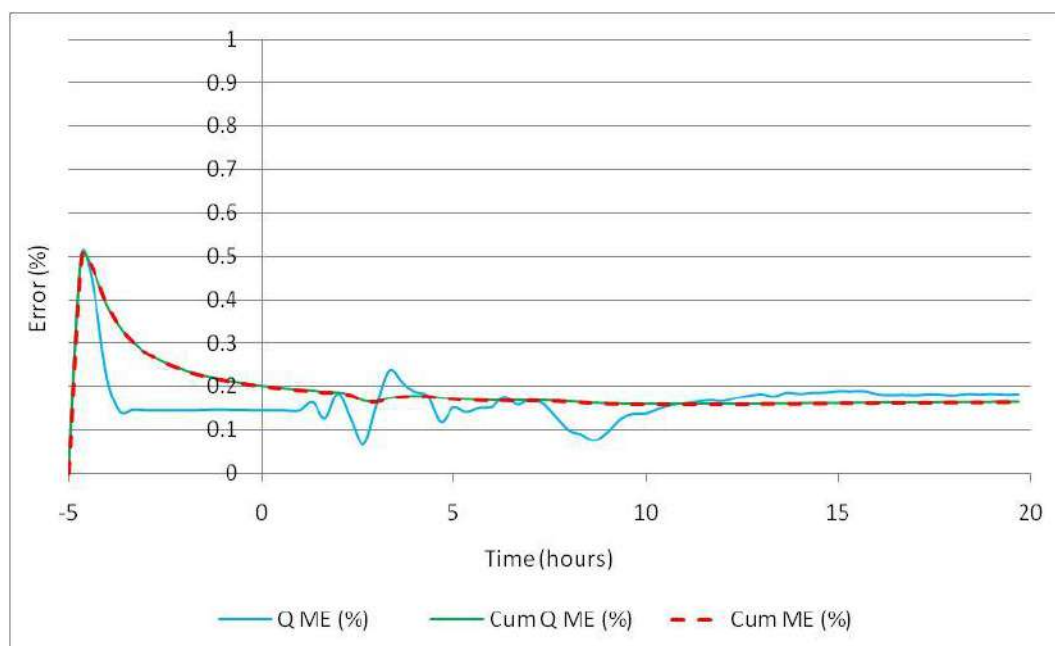


Figure 7-1 Mass balance plot, 0.1% AEP

7.1.2 Non Convergent ISIS Nodes

All warnings related to non-convergent ISIS nodes refer to the spill units and HT boundaries linking the ISIS channel to the Brodick Road FSA. It is not considered that these warnings are impacting adversely on the final model results.

7.2 Model Calibration and Validation

No historic flood information was available for validation of the model outputs.

7.3 Model Sensitivity

Sensitivity testing has been undertaken on the model outputs. This has been undertaken with the aim of increasing confidence in the conclusions drawn from the model outputs. Table 7-1 lists the sensitivity tests carried out and figures showing flood extents for all sensitivity tests are included in Appendix C of this report.

Run Name	Description
SEN01	Roughness factored by 1.2
SEN02	Roughness factored by 0.8
SEN03	Downstream boundary altered (see below)
SEN04 / SEN06	Culvert Inlet Unit test
SEN05	Overtopping of the Ashby Canal prevented (0.1% AEP)
SEN07	Half bore flows from the Ashby Canal added to Sketchley Brook

Table 7-1 Sensitivity tests

7.3.1 Material Roughness (SEN01 and SEN02)

The selection of material roughness values within hydraulic models is, to some extent, subjective. Without access to reliable calibration data, knowledge of the degree of sensitivity of a model to this parameter is therefore important.

A global change in roughness of plus and minus 20% was applied to the ISIS river sections, bridges and culverts. Two locations, upstream on the Sketchley tributary and downstream of the Brodick Road FSA, demonstrated extreme sensitivity to changes in roughness and therefore baseline roughness was unchanged.

For the 2D domain, two new versions of the material file (tmf) were created, with Manning's 'n' values factored by 1.2 and 0.8 to simulate a 20% change in roughness. Additionally, the roughness value in the ESTRY culvert was also changed by the same value.

The average (median) change in peak stage reported by the ISIS model was 0.06 m for SEN01 and -0.06 m for SEN02. Overall, impacts on predicted flood extents are negligible and no additional properties are at risk as a result of higher roughness.

There are two locations which show a reversed impact on flood levels, i.e. increasing roughness causes a reduction in peak stage and vice versa, discussed below.

Rugby Road Long Culvert

Minor instabilities within the culvert result in the reversed impacts, however open channel results upstream and downstream of the culvert do not exhibit this result.

Brodick Road FSA

Increasing roughness has resulted in a drop in stage (0.03m) in the vicinity of the rock weir. This is due to the increased water levels upstream altering the spilling mechanisms into the storage area and thus reducing flows in the 1D model. There is no impact on flood extent as a result of this anomaly.

7.3.2 Inflows

The sensitivity of the model to changes in inflows is illustrated by the range of design events run for this study.

There is negligible flooding predicted during the 20% AEP event; both the Brodick Road FSA and the FSA at the confluence of Sketchley Brook and Sketchley tributary are in operation.

Flooding of properties on East Close occurs in events equal to and greater than the 10% AEP. Flood extents for events up to the 0.5% AEP are not increased significantly as a result of higher flows. However, the 0.1% AEP results in a noticeable increase in flooding throughout the model. Additional out of bank flooding occurs at Featherston Drive, Nutt's Lane and Glenbarra Drive.

7.3.3 Downstream Boundary (SEN03)

The sensitivity of the model to downstream boundary changes was assessed by altering the HT boundary that is applied in both the ISIS and TUFLOW components of the model. The baseline 1% AEP model applies the 1% AEP peak stage from the River Anker (84.3 mAOD) to the downstream end of the ISIS model (based on an AASHTO 1:1 ratio). The ratio of the Harrow Brook catchment to the Anker catchment is 1:2 which falls between the AASHTO ratios of 1:1 and 1:10, therefore a sensitivity test using the 2% AEP (AASHTO 1:10 ratio) has been undertaken (84.28 mAOD).

There is a negligible impact on flood extents as a result of altering the Anker boundary.

7.3.4 Culvert Inlet Unit (SEN04 and SEN06)

During the model development, two locations (BAT1.006 Brodick Road and HAR1.033 A47) were observed where the loss coefficients applied to the culvert had a more pronounced impact on the results. Consequently loss coefficients for a culvert with wing walls were applied based on detailed guidance set out in the CIRIA Culvert Design Guide⁴ as shown in Table 7-2. This was considered more appropriate given the geometry of the channel upstream.

Parameter	ISIS Suggested Coefficient	BAT1.006 / HAR1.033 Revised
K	0.0098	0.026
M	2	1
C	0.0398	0.0385
Y	0.67	0.810
Ki	0.3	0.3

Table 7-2 Culvert Inlet Loss Coefficients

A check on the impact of the loss approach on final model runs was made using the 1% AEP event and the 0.1% AEP in two sensitivity tests: SEN04 re-set the coefficients to the ISIS suggested values and SEN06 removed the culvert inlet units from the model.

For the 1% AEP, altering the loss coefficients resulted in a small reduction (0.01m) in flood level upstream of the culverts. Removing the culvert inlet units reduced levels upstream of BAT1.006 by 0.053m and by 0.008m upstream of HAR1.033. There is no observable change in flood extents.

For the 0.1% AEP, removing the culvert inlet unit from BAT1.006 lowered the peak stage by 0.2m. Using the ISIS suggested loss coefficients lowered the peak stage by 0.1m. A negligible impact on flood extents occurs as a result. At HAR1.033, removing the inlet unit lowers peak

⁴ CIRIA (2010) C689 Culvert Design and Operation Guide

stage by 0.04m and using suggested loss coefficients increases the peak stage by 0.03m. There is no observable change in flood extents.

7.3.5 Canal Overtopping (SEN05)

Results for the 0.1% AEP on the Sketchley Brook are close to the level of the Ashby Canal as indicated by the LiDAR data. No detailed survey data was available to confirm the levels of the canal and thus whether or not the canal embankment would be overtopped in the 0.1% AEP. Therefore a sensitivity test was undertaken which enforced a level along the canal to prevent overtopping. The impact on flood extents was constrained to the area immediately upstream and downstream of the canal. Flooding of the industrial estate on Nutt's Lane is prevented in the SEN05 model run. Flood depths (but not extents) are increased upstream of the canal by around 0.03m.

7.3.6 Canal Overflows (SEN07)

As described in Section 5.4.1 a sensitivity test to determine the impacts on water levels of increasing the inflow from the Ashby Canal to the Sketchley Brook was carried out (flows were increased from quarter bore to half bore). Flood extents along Nutt's Lane were increased as a result, adding three additional properties to the 1% AEP flood outline. Downstream of this point, flood extents on rural land were also increased.

7.3.7 Sensitivity Test Conclusions

Overall, the model is not overly sensitive to the parameters tested although there are two key areas which exhibit a greater level of sensitivity and the potential for instabilities:

- Downstream of Brodick Road FSA
- Sketchley tributary upstream sections

However, peak stage results remain stable throughout the model simulation and the mass balance error is low.

Although structures BAT1.006 and HAR1.033 do exhibit some sensitivity to the loss coefficients applied, the topography of the channel ensures that there is a negligible impact on flood extents.

The largest change in flood extents occurs as a result of preventing the overtopping of the Ashby Canal from the Sketchley Brook. It is recommended that survey data along the canal embankment is collected to refine the model in this location.

Flood risk to properties downstream of the Ashby Canal overflow to the Sketchley Brook is increased by assuming a higher volume of flow enters the brook from the canal. It is therefore recommended that further investigations into overflow rates are carried out.

8 Model Results

8.1 Design Simulations

8.1.1 Tabular 1D ISIS Results

Peak level and flow results for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1.33% AEP, 1% AEP, 1% AEP (with climate change), 0.5% AEP and 0.1% AEP design simulations are included in the final NFCDD files. Locations of river sections (ISIS nodes) are shown in Appendix A of this report.

8.1.2 Design Extent, Depth, Velocity and Hazard Outputs

Flood extent drawings have been produced for the 5% AEP, 1% AEP and 0.1% AEP and are included in Appendix E. Flood outlines and ASCII grids for all events are provided in digital format alongside this report.

8.2 Results Discussion

The following section discusses the main flooding mechanisms shown by the model outputs.

Sketchley Brook

Upstream of Rugby Road, flooding is constrained to undeveloped areas for the 20% AEP, though even this event exceeds the capacity of the Flood Relief Basin, with flooding to gardens on East Close resulting. Flooding of properties on East Close and Bridge Road occurs in the 10% and 5% AEP from an extension of the mechanism described above, with these flows able to open up a significant flow path that eventually overtops Rugby Road to re-join the brook downstream.

In the 2% AEP additional properties on the junction of Brookside / Holt Road are flooded as the Sketchley Brook tributary overtops the culvert which links it to the Sketchley Brook. For events up to the 0.5% AEP, flood extents remain broadly similar with no additional properties flooding. However, in the 0.1% AEP additional properties are flooded on Holt Road / Featherston Road as the Sketchley Brook tributary also overtops these structures.

Downstream of Rugby Road, flood extents should be viewed with caution due to the issues identified with the LiDAR data in respect of the new development site. It is noted that there is significant flooding immediately upstream of the Ashby Canal for the 0.1% AEP which will need to be accommodated in the new development and that a major flow path is also shown to affect the sewage works site for this event.

Downstream of the Ashby Canal, the industrial estate at Nutt's Lane is flooded in the 0.1% AEP. This flooding mechanism is however associated with overtopping of the Ashby Canal and there is a significant reduction in flood extent when these flows are cut off, as shown by sensitivity testing (see Section 7.3.5).

Flooding of properties on Nutt's Lane occurs for events with a magnitude equal to and greater than the 2% AEP. For events greater than the 2% AEP, the A5 (Watling Street) would also be overtopped close to the point at which it passes under the railway line. Overtopping flows would flood farmland at Hydes Pastures.

Harrow Brook

Upstream of Brodick Road FSA, flooding is constrained to undeveloped areas for all modelled events. The FSA is in operation for all events but is overtopped only by the 0.1% AEP.

Between the FSA and the A5 (Watling Street), all modelled events remain in or close to the brook channel.

Downstream of the A5, out of bank flooding occurs for events with a magnitude equal to and greater than the 10% AEP. This flooding occurs on farmland. For the 0.1% AEP event there is predicted to be considerable ponding of flows behind the railway embankment

8.3 Standard of Protection

Brodick Road FSA

The embankment at Brodick Road FSA is overtopped only in the 0.1% AEP event therefore the standard of protection afforded is considered to be 0.5% AEP. An assessment of overtopping flows has been made as shown in Figure 8-1.

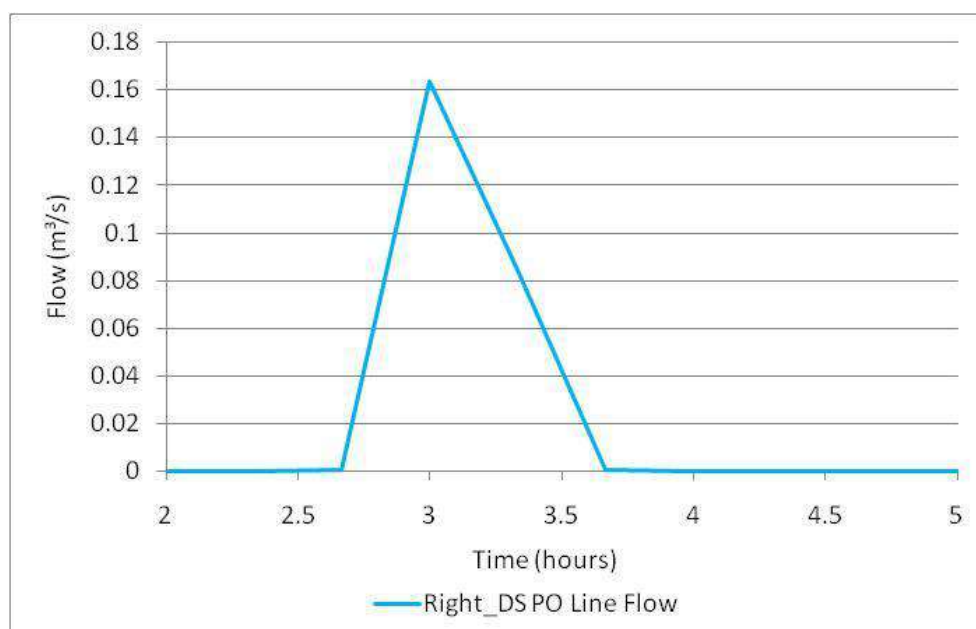


Figure 8-1 Flow Over Brodick Road FSA Embankment, 0.1% AEP

The total volume passing over the embankment in the 0.1% AEP is 299 m³. Spread over the 11,480 m² within the FSA, this equates to a change in depth within the FSA of just 0.03 m. A discussion on the ecological value of the FSA follows in Section 8.5.

Longshoot Flood Wall

Flooding from the Harrow Brook reaches the flood wall at The Longshoot. The level of the flood wall ranges from 88.51 mAOD to 88.77 mAOD (data taken from NFCDD). The peak 0.1% AEP level is 87.87 mAOD which is well below the crest of the wall therefore the standard of protection is considered to be 0.1% AEP.

No assessment has been made regarding the flood risk from the minor watercourse as this is outside the project scope.

8.4 Areas Benefitting from Defences

The design simulations discussed previously are all defended runs. Undefended runs for the 1% AEP and 0.1% AEP have been carried out through the removal of the embankment at Brodick Road FSA and the flood wall at The Longshoot.

The ISIS Spill unit modelling the throttle structure controlling the outflow from Brodick Road was altered to match the upstream channel section. A Z line was applied to the embankment on the right bank of the Harrow Brook which lowered ground levels to match those in the flood storage area.

The Z line enforcing the Longshoot wall was removed from the 2D domain.

0.1% AEP

The peak stage in the Brodick Road FSA is reduced by approximately 0.74 m as a result of removing the embankment. Downstream of the embankment, in the informal storage area, peak stage is increased by 0.04 m as illustrated in Figure 8-2. The canal embankment prevents any significant increase in flood extents downstream, though peak flows through the culvert do increase slightly ($5.3 \text{ m}^3/\text{s}$ to $5.5 \text{ m}^3/\text{s}$). There is a reduction in flooding on the allotments to the south of the FSA for the undefended run.

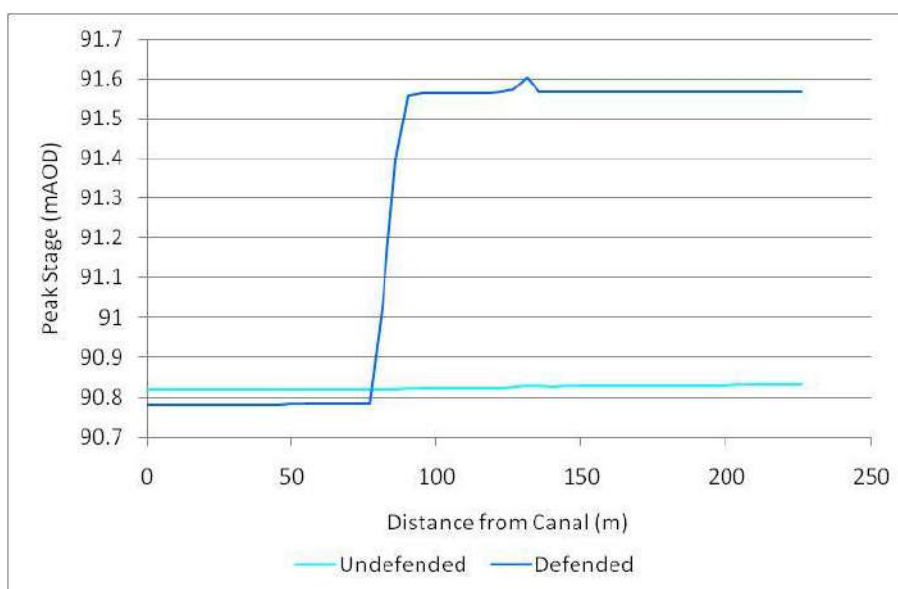


Figure 8-2 Peak Stage Upstream and Downstream of Brodick Road FSA Embankment, 0.1% AEP

Upstream of Brodick Road FSA, there are very small increases in flood extents for the undefended run. These increases are within areas of existing open space and consequently no additional properties are at risk.

Removal of the wall at The Longshoot results in flooding extending a further 20 m into the gardens of properties on The Longshoot. No additional properties are at risk. Downstream of this point, flood extents are increased in the vicinity of the railway embankment although no flooding of the railway itself occurs.

1% AEP

The peak stage in the Brodick Road FSA is reduced by approximately 0.7 m as a result of removing the embankment. Downstream of the embankment, in the informal storage area, peak

stage is increased by 0.17 m as illustrated in Figure 8-3. The canal embankment prevents any significant increase in flood extents downstream.

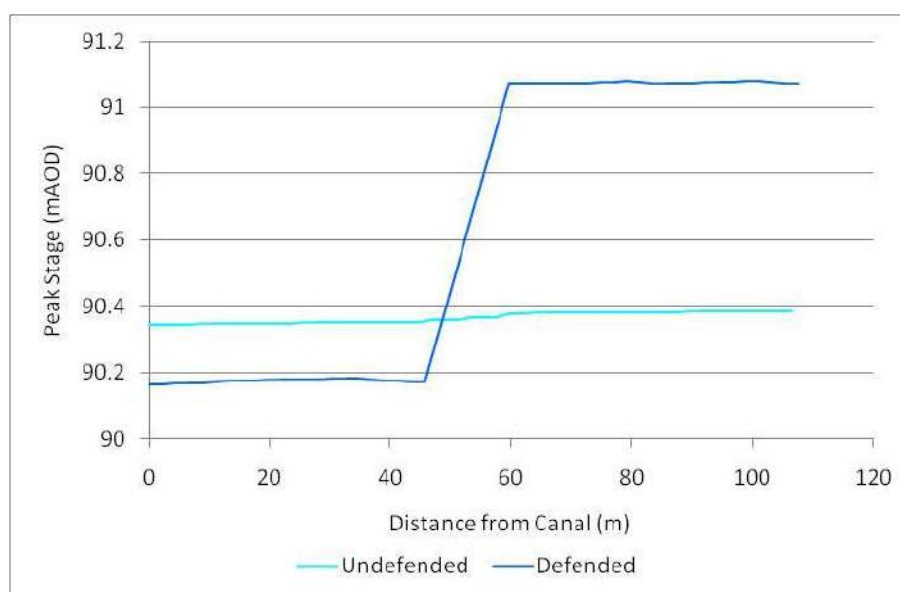


Figure 8-2 Peak Stage Upstream and Downstream of Brodick Road FSA Embankment, 1% AEP

Removal of the wall at The Longshoot does not result in an increase in flooding at this location. Downstream of this point, there is additional flooding adjacent to the railway embankment although no flooding of the railway itself occurs.

8.5 Brodick Road FSA High Level Ecological Review

8.5.1 Introduction

Hyder Consulting have been commissioned by the Environment Agency to review the requirement to de-silt and remove vegetation from a flood storage facility located on the Batting and Harrow Brook. As part of this study a high level ecological desk based review was conducted to identify any potential ecological constraints that may be present.

8.5.2 Methodology

A high level desk-based review of existing ecological information was collated from a number of sources, as described below.

- The Multi-Agency Geographical Information System (MAGIC) website (www.magic.gov.uk) was used to search for any statutory designated sites of nature conservation importance Sites of Special Scientific Interest, Special Areas of Conservation and Special Protection Areas (SSSI/SAC/SPA) and ancient woodlands within a 2 km radius of the centre of the site (Ordnance Survey grid reference. 440790, 293810).
- Ordnance Survey maps, aerial photographs and site photographs were also reviewed.

It should be noted that no ecological walkover survey was conducted as part of this appraisal.

8.5.3 Potential Constraints

Habitats

No statutory designated sites of nature conservation importance or ancient woodlands were found within 2 km of the site. It is therefore considered that these sites or habitats will not be affected by the proposals.

A review of aerial photographs and site photographs revealed that the flood storage facility has been colonised by fen and marshy grassland vegetation largely comprising Meadowsweet (*Filipendula ulmaria*), Great Willowherb (*Epilobium hirsutum*), and Bulrush (*Typha latifolia*). The banks of the facility supported dense scrub dominated by Hawthorn (*Crataegus monogyna*). The fen and marshy grassland vegetation appeared to be moderately species-rich and is considered to be of some nature conservation value.

Legally protected species

Invertebrates

It is considered that the fen and marshy grassland will support a range of common invertebrate species but no habitats likely to support rare or endangered invertebrate species were identified.

Amphibians

The fen vegetation may provide suitable foraging habitat for common amphibian species such as common frog (*Rana temporaria*) and common toad (*Bufo bufo*) but no areas of permanent open water were identified. The site is, therefore, unlikely to support a breeding population of great crested newts (*Triturus cristatus*). In addition, a review of the relevant Ordnance Survey maps and aerial photographs did not reveal the presence of any areas of open water within 200m of the site that may support a breeding population of great crested newts. It would appear unlikely that great crested newts would be present on the site.

Reptiles

The banks of the flood storage facility were considered potentially suitable for basking and hibernating reptile species, whilst the fen and marshy grassland was considered potentially suitable foraging habitat. The facility may support a small population of common reptile species such as slow worm (*Anguis fragilis*) and grass snake (*Natrix natrix*).

Breeding Birds

The scrub on the banks of the facility is likely to support a limited number of breeding bird species characteristic of scrub habitat. The dense areas of fen and marshy grassland may also support a limited number of scarce breeding species including grass hopper warbler (*Locustella naevia*), reed warbler (*Acrocephalus scirpaceus*) and sedge warbler (*Acrocephalus schoenobaenus*).

Mammal Species

The scrub habitat on the banks of the facility was considered potentially suitable for badgers (*Meles meles*) to excavate a sett. The marshy grassland and fen habitat, together with the surrounding gardens also provide suitable foraging habitat for badgers. It is therefore considered possible that badgers may be present in the locality.

The banks of the watercourse flowing through the facility appeared to have soft banks suitable for water voles (*Arvicola amphibius*) burrows and the aquatic and emergent vegetation represents suitable foraging habitat. Therefore it is considered that water voles may be present.

The watercourse is relatively small in size (1 m wide) and unlikely to support a significant population of fish. It is therefore considered unlikely that the site and its associated watercourse would be of value to otters (*Lutra lutra*). However, the cover provided by the fen, marshy grassland and scrub habitat appeared to be sufficiently dense to provide cover for otters and it is therefore possible that a lying up site could be present.

The wetland habitats were also considered potentially suitable to support foraging bats species, should any bats be roosting nearby. However, no mature trees or other structures were visible in the photographs that could potentially support roosting bats are located within or adjacent to the flood storage area.

8.5.4 Recommendations

Currently modelling suggests that there may not be a requirement to remove vegetation and silt from the flood storage facility. However, if it is deemed that there will be a requirement to remove vegetation and silt in order for the flood storage facility to fulfil its engineering function, then the following recommendations should be followed, to maintain the ecological value of the site and to ensure compliance with protected species legislation.

- A walkover survey should be conducted (at an appropriate time of year, April to October) to confirm the presence or otherwise, of legally protected species in particular water voles, badgers and otters. If evidence of the presence of these species is identified, then a suitable mitigation strategy will need to be produced and agreed with Natural England, prior to works commencing.
- If it is necessary to remove wetland vegetation this should be cleared outside of the bird breeding season. That is the works should take place between October to early February inclusive.
- If any scrub on the banks needs to be removed this should also be coppiced at ground level during the winter (to avoid disturbance to nesting birds, see above re timings). However, the stumps and roots should not be removed until late April or May when reptiles have emerged from hibernation. It is also recommended that cut vegetation and scrub is kept short (less than 5cm) once cleared to encourage reptiles to disperse and move out of the works area.
- The fen and marshy grassland vegetation was considered to be of some intrinsic nature conservation value. Therefore it would be beneficial if pockets of vegetation could be left to encourage the re-vegetation of similar plant species, once clearance and de-silting works have occurred.

8.5.5 Future Management of the Storage Facility

Whilst it is recognised that the flood storage facility has an engineering role to perform, the ecological appraisal has identified that the facility has naturalised and now supports habitats of some intrinsic nature conservation value and which could potentially provide habitat features supporting legally protected species.

It would be beneficial if an ecology walkover survey could be completed and a management brief prepared for the flood storage facility outlining how the site could be managed in the future to maintain and enhance its biodiversity value whilst not compromising its engineering function.

9 Limitations and Future Use

The study has produced hydrological and hydraulic modelling targeted to meeting the aims and objectives that were set out at project inception. This section highlights any assumptions made or limitations to the modelling approach where it exists.

9.1 Limitations

- No historic data is available to validate the model outputs
- Missing LiDAR data and 'as-built' channel data for the Sketchley Brook development has resulted in uncertainty in the flood extents upstream of the Ashby Canal.
- Limited information on the Ashby Canal embankment and overflow has resulted in uncertainty in the flood extents both upstream and downstream of the Ashby Canal.

9.2 Future Uses

The hydrology and hydraulic models produced for the study are deemed suitable for use in addressing the study aims and objectives. It is accepted that the Environment Agency may wish to use and/or adapt the model to meet future needs. Whilst this report cannot cover all possible future eventualities, Table 9-1 is provided below for initial guidance in this respect.

Future Use	Current Model Appropriate	Additional Work to Realise Future Use
Flood warning trigger levels	Yes	Sufficient detail is available within the model to identify trigger levels. Threshold data is required to determine actual property flood levels.
Definition of flood warning areas	Yes	Outputs from the model could be used to define flood warning areas.
Design of flood alleviation schemes	Partially	There may be some areas of the model which would go some considerable way to informing the design of a flood alleviation scheme. It would be beneficial to collect anecdotal data to validate the model prior to its use for design of schemes.
Assessment of residual risks due to blockages	Yes	
Impacts of changing the design of a structure	Partially	See 'design of flood alleviation schemes'

Table 9-1 Summary of potential model future uses and additional work required

10 Conclusions

- An ISIS-TUFLOW model of the Harrow and Sketchley Brooks has been constructed in order to improve the understanding of flood risk along the watercourses
- The model runs stably for the design events assessed as part of this report as well as the seven sensitivity tests carried out.
- Predicted flood extents are not overly sensitive to changes in roughness or downstream boundary conditions
- Uncertainty surrounds the modelled flood extents upstream of the Ashby Canal crossing on the Sketchley Brook due to inaccurate topographic data on the development site.
- The elevation of the Ashby Canal embankment as it crosses the Sketchley Brook and the overflow rate from the canal into the brook influence the flood extents and therefore additional data is required to improve confidence in modelled outputs.
- For all modelled design events, where out of bank flooding occurs, the majority of this is in areas of open space though there are properties potentially at risk for relatively high frequency events (10% AEP). Key areas where properties are at risk are East Close, Bridge Road, on the junction of Brookside / Holt Road and at Nutt's Lane on the Sketchley Brook.
- The Brodick Road FSA has a standard of protection of 0.5% AEP and the flood wall at The Longshoot has a standard of protection of 0.1% AEP
- No additional properties are at risk as a result of removing the Brodick Road FSA embankment or the flood wall at The Longshoot. Minor changes in flood extents are observed for the 1% AEP and the 0.1% AEP.
- A high level ecological assessment has been undertaken for the Brodick Road FSA

11 Recommendations

The following recommendations have been identified:

- The section of the model through the Sketchley Brook development should be updated to include: as built channel and bridge sections, 2D roughness and floodplain topography
- Further information on overflow spills from the Ashby Canal into the Sketchley Brook would improve confidence in the modelled outputs.
- Level data should be obtained for the Ashby Canal as it crosses the Sketchley Brook to determine whether or not the 0.1% AEP event over tops the canal embankment.
- An assessment of culvert blockage scenarios should be undertaken using the hydraulic model.
- Property threshold level data should be collected to confirm the number of properties which are potentially at risk from internal flooding.
- Once the model has been updated as above, it may be used to investigate flood alleviation options, particularly on the Upper Sketchley Brook
- Consideration as to the future use of Brodick Road FSA should be made. The potential for flood alleviation on the Harrow Brook is currently relatively low while its ecological status could be further developed.

Appendix A1

1D Structures

Structure	Model Node (u/s)	ISIS Unit(s)	Notes
Battling Brook			
Footbridge behind Pentland Close	BAT1.020U	Symmetrical Culvert	Double barrelled culvert
Weir behind Pentland Close	BAT1.019WrU	Spill	Concrete stepped weir in channel downstream of culvert
Roston Drive Road Bridge	BAT1.018BrU	Orifice	Access bridge with very small opening - surcharged therefore orifice used for stability
Weir at Roston Drive	BAT1.017WrU	Spill	Built of mud / pebbles
Footbridge behind Crammond Close	BAT1.013BrU	Arch Bridge	
Glenbarr Drive Road Bridge	BAT1.011BrU	Arch Bridge	
Footbridge behind Lochmore Close	BAT1.008BrU	Arch Bridge	
Brodict Road Bridge	BAT1.006BrU	Symmetrical Culvert	Spills in 2D domain
Weir in Brodict Road FSA	BAT1.004WrU	Spill	Rock and grass weir in channel
Footbridge in Brodict Road FSA	BAT1.003BrU	Arch Bridge	
Flow Control at Brodict Road FSA	BAT1.002ThrU	Spill	Narrow concrete channel section used to throttle flows out of Brodict Road FSA
Harrow Brook			
Culvert under Ashby Canal	HAR1.044BrU	Symmetrical Culvert	
Weir Upstream of A47 Road Culvert	1.033WrUp	Spill	Brick weir
A47 (Dodwells Road) Culvert	HAR1.033BrU	Symmetrical Culvert	
A5 Culvert	HAR1.032BrU	Symmetrical Culvert	Double barrelled culvert

Access track from The Long Shoot	HAR1.019BrU	Arch Bridge	
Railway Bridge	HAR1.016BrU	Symmetrical Culvert	Spills in 2D domain
Flood Relief Channel on Railway Bridge	FR02_Up	Flood Relief (Orifice)	Higher level culvert through railway embankment
Hydes Pastures Footbridge	HAR1.012BrU	Arch Bridge	
Wheatcroft Farm Access Track	HAR1.006BrU	Arch Bridge	
Sketchley Brook			
Culvert under Featherston Drive	SKT550CuLU	Symmetrical Culvert	Taken from new survey, January 2013. Spills in 2D domain.
Culvert under Holt Road, left barrel	SKT432CLU	Symmetrical Culvert	Taken from new survey, January 2013. Spills in 1D domain.
Culvert under Holt Road, right barrel	SKT432CRU	Flood Relief	Modelled as flood relief for stability as invert level is higher than left barrel
Footbridge in recreation ground	SKT274BrU	Arch Bridge	Taken from new survey, January 2013. Spills in 1D domain.
Box culvert under Brookside	SKT064CuUp	Symmetrical Culvert	Taken from new survey, January 2013. Spills in 2D domain.
Culvert between Brookside and East Close running beneath recreation ground to Rugby Road	87_Cu	Symmetrical Culvert	Upstream of model extents but included in supplied FRA model. Not linked to TUFLOW.
Proposed redevelopment footbridge	P7.8u	Arch Bridge	No spill modelled in supplied model.
Proposed redevelopment footbridge	P7.6u	Arch Bridge	No spill modelled in supplied model.
Proposed redevelopment road bridge	PC7.42	Rectangular Conduit	Spills in 2D domain. However no post development levels supplied.
Proposed redevelopment footbridge	P5.2u	Arch Bridge	No spill modelled in supplied model.
Existing Brookfield Road Bridge	X04_Bu	Arch Bridge	Included in FRA model
Proposed redevelopment road bridge	PC2.2	Rectangular Conduit	Spills in 2D domain. However no post development levels supplied.
Ashby Canal Siphon	13_Cu	Symmetrical Culvert	Included in FRA model

Access to industrial unit off Hammonds Way	1.029BrU	Arch Bridge	Not included in FRA model. Altered sections upstream and downstream to allow this structure to be included.
Access to industrial unit off Hammonds Way	1.028BrU	Arch Bridge	Downstream of FRA model
Access to industrial unit off Hammonds Way	1.026BrU	Arch Bridge	
Hammonds Way Road Bridge	1.025BrU	Symmetrical Culvert	Spills in 2D domain
Weir upstream of A5	1.024WrU	Spill	Irregular, dilapidated concrete weir in channel.
A5 culvert	1.023BrU	Symmetrical Culvert	Spills in 2D domain
Hydes Pastures Footbridge	1.018BrU	Arch Bridge	
Hydes Pastures Footbridge	1.009BrU	Arch Bridge	
Hydes Pastures Footbridge	1.007BrU	Arch Bridge	

Appendix A2

Hydraulic Model Schematics

A1 Hydraulic Model Schematic

Hydrological Report

Sensitivity Analysis

- C1 Hinckley Roughness Sensitivity Test (SEN01 and SEN02) Tile H1
- C2 Hinckley Roughness Sensitivity Test (SEN01 and SEN02) Tile H2
- C3 Hinckley Roughness Sensitivity Test (SEN01 and SEN02) Tile H3
- C4 Hinckley Roughness Sensitivity Test (SEN01 and SEN02) Tile H4
- C5 Hinckley Roughness Sensitivity Test (SEN01 and SEN02) Tile H5
- C6 Hinckley Downstream Boundary Sensitivity Test (SEN03) Tile H1
- C7 Hinckley Downstream Boundary Sensitivity Test (SEN03) Tile H2
- C8 Hinckley Downstream Boundary Sensitivity Test (SEN03) Tile H3
- C9 Hinckley Downstream Boundary Sensitivity Test (SEN03) Tile H4
- C10 Hinckley Downstream Boundary Sensitivity Test (SEN03) Tile H5
- C11 Hinckley Culvert Sensitivity Test (SEN04 and SEN06) Tile H3
- C12 Hinckley Culvert Sensitivity Test (SEN04 and SEN06) Tile H4
- C13 Hinckley Canal Overtopping Test (SEN05) Tile H1
- C14 Hinckley Canal Overtopping Test (SEN05) Tile H2
- C15 Hinckley Canal Overtopping Test (SEN05) Tile H5
- C16 Hinckley Canal Overflow Test (SEN07) Tile H1
- C17 Hinckley Canal Overflow Test (SEN07) Tile H2
- C18 Hinckley Canal Overflow Test (SEN07) Tile H5

Hydraulic Model Files and Documentation

Appendix E

Mapped Outputs

- E1 Hinckley 5% AEP Design Flood Outline Tile H1
- E2 Hinckley 5% AEP Design Flood Outline Tile H2
- E3 Hinckley 5% AEP Design Flood Outline Tile H3
- E4 Hinckley 5% AEP Design Flood Outline Tile H4
- E5 Hinckley 5% AEP Design Flood Outline Tile H5
- E6 Hinckley 1% AEP Design Flood Outline Tile H1
- E7 Hinckley 1% AEP Design Flood Outline Tile H2
- E8 Hinckley 1% AEP Design Flood Outline Tile H3
- E9 Hinckley 1% AEP Design Flood Outline Tile H4
- E10 Hinckley 1% AEP Design Flood Outline Tile H5
- E11 Hinckley 0.1% AEP Design Flood Outline Tile H1
- E12 Hinckley 0.1% AEP Design Flood Outline Tile H2
- E13 Hinckley 0.1% AEP Design Flood Outline Tile H3
- E14 Hinckley 0.1% AEP Design Flood Outline Tile H4
- E15 Hinckley 0.1% AEP Design Flood Outline Tile H5

C Channel Survey Data



Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information has been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design, The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

All dimensions to be checked on site prior to design and construction.

ARK VALVE	AV	WATER TAP	TAP
BOLLARD	BH	TEMPORARY BENCH MARK	TBM
BOX	BO	TELEPHONE CABLE BOX	TCS
BUS STOP	BS	TELEPHONE POST	TEL
CONCRETE COVER	BT	THRESHOLD LEVEL	TL
BT BOX	BTB	TRAFFIC LIGHT	TOL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
CAN	CA	TELEGRAPHIC POLE	TP
DOWN PIPE	CD	UNABLE TO LEVEL	U/L
INSPECTION KERB	CK	UPPER PIPE	UP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHCUP	WU
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FW		
INSPECTION COVER	FI		
GULLY	GU		
GATE POST	GP	SURVEY STATION	CS1
GAZ VALVE	GV	BUSHES	
INSULATED JOINT	IJ		
INSPECTION COVER	IC		
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP		
LITTER BIN	LB	TREES	
MARKER POST	MP		
MALE POST	ML		
PO	PO		
RODDING EYE	RE	GATE	
ROUTE HIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	—X—X—
SE	SE	FENCE	—S—S—
SOFFIT LEVEL	SF	OVERHEAD CABLES	—OH—OH—
SIGNAL POST	SP	FOUL WATER	FW FW
ST	ST	GAZ MANHOLE	GM GM
SIGNALS AND TELECOMS BOX	STB	UG POWER LINE	—PL—PL—
SIGNALS AND TELECOMS CABLE	STC	UG POWER LINE	—PL—PL—
SIGNALS AND TELECOMS POST	STP	UG TELEPHONE	—UL—UL—
STOP TAP	ST	WATER MAIN	WM WM
STOP VALVE	SV		
STORM WATER	SW		

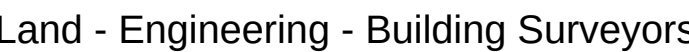
Station	Description	Eastings	Northings	Height

Grid: *OS National Grid* **Datum:** *Ordnance Datum Newlyn*
Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.
A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.
No scale factor has been applied to the survey

WATERCOURSE SURVEY AT Sketchley Brook, Hinckley (Cross Sections)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD



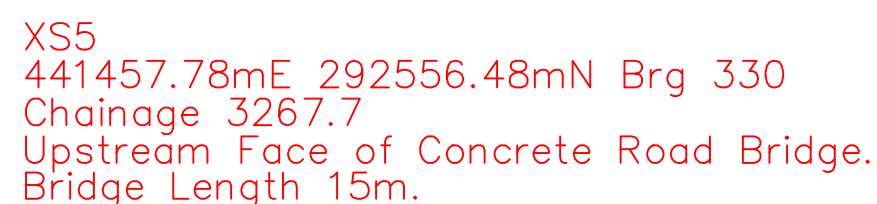
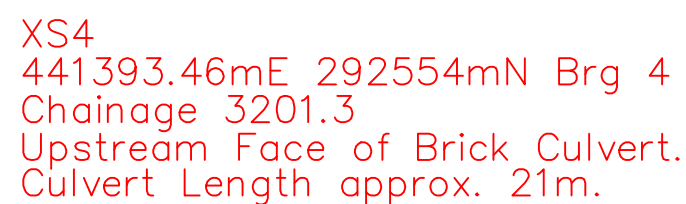
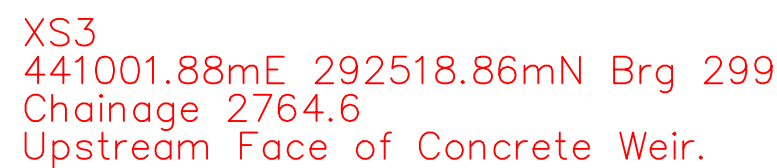
2 Arden Court, Arden Road, Alcester
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 Tel: 01789 764420

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Web Site: www.gcsurveys.co.uk



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(Date):		Notes:		Name:	
Drawn: MS		Checked: SC		Date: 30/10/23	
File Name: GCS-JBA-Sketchley Brook-1				Sheet size: A1	
				Sheet 2 of 3	



This survey should only be relied upon for its original purpose. Grantham Coates Surveys Limited accepts no responsibility for use of this plan outside of the original remit, or by use of any party other than the original client.

Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information has been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

All dimensions to be checked on site prior to design and construction.

Legend

[illegible]

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: *OS National Grid* **Datum:** *Ordnance Datum Newlyn*
Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.
A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.
No scale factor has been applied to the survey

Title:

WATERCOURSE SURVEY AT Sketchley Brook, Hinckley (Cross Sections)

Client:

JBA CONSULTING
The Library
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Land - Engineering - Building Surveyors

2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN



Drawing No: GCS/JBA/Sketchley Brook/1	Rev: -
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Date:	Notes:	Name:	Rev:

Drawn: MS	Checked: SC	Scale: 1:100	Date: 30/10/23
File Name: GCS-JBA-Sketchley Brook-1		Sheet size: A1	Sheet: 3 of 3

D Key Hydraulic Structures

Included in model? (state reason if not):	Yes
Model label:	P3
Type:	Rectangular culvert with width of 6.09m.
How has structure been modelled?	The structure has been represented as a rectangular conduit unit in Flood Modeller. Overtopping flow has been modelled in the 2D domain.
	

Included in model? (state reason if not):	Yes
Model label:	SKBR_14
Type:	Sprung arch culvert with width of 1.41m.
How has structure been modelled?	The structure has been represented as a sprung arch conduit unit in Flood Modeller. Overtopping flow has been modelled in the 2D domain.
	

Included in model? (state reason if not):	Yes
Model label:	1.024U
Type:	Weir
How has structure been modelled?	The structure has been represented as a weir unit in Flood Modeller. Overtopping flow has been modelled in the 1D domain.

 gcsurveys.co.uk
--

Included in model? (state reason if not):	Yes
Model label:	1.023U
Type:	Rectangular conduit with a width of 4.54m.
How has structure been modelled?	The structure has been represented as a rectangular conduit unit in Flood Modeller. Overtopping flow has been modelled in the 2D domain.
 gcsurveys.co.uk	

E Hydrology Report

Flood estimation report: Sketchley Brook Hydraulic Modelling Study

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

1	Method statement	2
2	Locations where flood estimates required	10
3	Statistical method	14
4	Revitalised flood hydrograph 2 (ReFH2) method	18
6	Discussion and summary of results	20
7	Annex A – Pooling Groups	24
8	Annex B – Design Hydrographs	25
9	25	

Approval

	Name and qualifications	Date
Method statement prepared by:	Sam Cogan MSc, BSc	19/10/2023
Method statement reviewed by:	David Cameron BSc PhD MCIWEM CWEM CSci	30/10/2023
Calculations prepared by:	Sam Cogan MSc, BSc	23/10/2023
Calculations reviewed by:	David Cameron BSc PhD MCIWEM CWEM CSci	30/10/2023

Revision History

Revision reference	Date issued	Amendments	Issued to

Abbreviations

AMAX	Annual Maximum
AREA	Catchment area (km ²)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CPRE.....	Council for the Protection of Rural England
FARL.....	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED.....	Median Annual Flood (with return period 2 years)
ReFH.....	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBEXT1990.....	FEH index of fractional urban extent
URBEXT2000.....	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

Note on flood probability

This document quotes the probability of a flood magnitude in terms of a return period based on analysis of annual maximum (AMAX) floods. The return period of a flood on the AMAX scale is the average interval between AMAX floods of that magnitude or greater. The inverse of the AMAX return period is the annual exceedance probability (AEP).

Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. AEP can be helpful when presenting results to non-specialists who may associate the concept of return period with a regular rather than an average interval.

Return period can also be measured on the peaks-over-threshold (POT) scale as the average interval between floods of that magnitude or greater. The difference between AMAX and POT return periods is only important for short return periods (under 10 years).

The table below is provided to enable quick conversion between these different measures.

AMAX return period (years)	n/a	2	5	10	20	30	50	75	100	200	1,000
AEP (%)	n/a	50	20	10	5	3.33	2	1.33	1	0.5	0.1
POT return period (years)	1	1.5	4.5	9.5	20	30	50	75	100	200	1,000

1 Method statement

1.1 Requirements for flood estimates

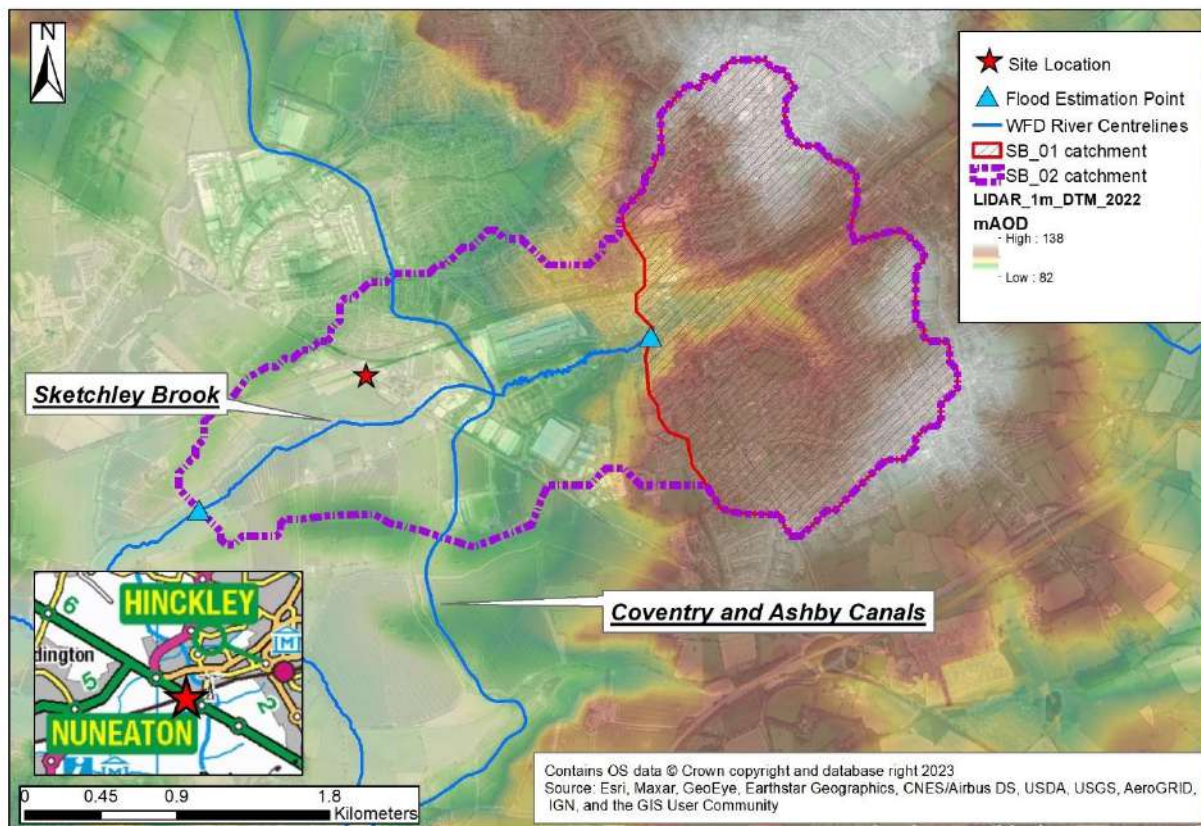
Overview - Purpose of study - Peak flows or hydrographs? - Range of return periods and locations	ADC Infrastructure Ltd have been appointed to improve sections of the A5 in Hinckley (approx. NGR: SP 40640 92675). The potential highway works comprise minor lowering of the carriageway where the A5 crosses a railway bridge. As this area falls within Flood Zone 2 and 3 of the Sketchley Brook (according to the EA Flood Map for Planning), the proposed work could exacerbate flood risk to the highway and/or to third-party land. The Sketchley Brook is a 'main river' designated watercourse which falls within the remit of the Environment Agency and for which a detailed hydraulic model is available. The model was last updated in 2013 and common practice would suggest it contains channel cross-section data from earlier versions. Up-to-date hydraulic modelling is therefore required to refine and accurately assess flood risk in relation to the A5 railway bridge and develop flood mitigation measures (if required) to ensure the lowering does not increase flood risk elsewhere. As part of the scope of this project, hydrology estimates are therefore required for input to the hydraulic model of the Sketchley Brook. This document details the hydrological assessment undertaken to derive the hydraulic model inflows. Peak flow estimates and hydrographs are required for two flow estimation points (FEP) for the Sketchley Brook. Peak flow estimates and hydrographs have been derived for the following annual exceedance probabilities (AEP) events: 50%; 3.33%; 1%; and 0.1%. Based on 2023 Environment Agency climate change allowance guidance¹, the proposed development site is located within the Tame Anker and Mease Management Catchment. For the '2080' scenario, the Central allowance climate change uplift is 22%. This has been applied to the 1% AEP event peak flows. Peak flows for the Higher allowance (30% uplift) have also been calculated. Peak flow estimates and hydrographs derived from the hydrological analysis will be incorporated into a 1D-2D hydraulic model capable of simulating flood extents, levels and flows through time in relation to the development site.
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1.2 The catchment

Map (Include river network, catchment boundary and gauging stations)

1 Environment Agency (2023). Guidance: Flood risk assessments: climate change allowances. [Source: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#Select-the-peak-river-flow-allowances-to-use-for-your-assessment>].

LOY_JBAU_XX_00_RP_HO_0001_S01_P02_JBA FEH calculation record.docx



Description

Include topography, climate, geology, soils, land use and any unusual features that may affect the flood hydrology.

Sketchley Brook, including contributing watercourses and urban drainage areas, drains an area of approximately 7km² to the downstream hydraulic model boundary. The general elevation trend of the larger study catchment is a decline from north east to south west as land falls from 138mAOD to 84mAOD.

Underlying bedrock geology of the study catchment consists of Mercia Mudstone Group - Mudstone. Superficial deposits of the catchment consist of Glacial sand and gravel and Till. Typical soils across the study catchment are slightly acid loamy and clayey soils with impeded drainage to the upper reaches and slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils².

The underlying bedrock, superficial deposits and soil types would indicate that the fluvial response to rainfall based on soil properties would likely be rapid due to the underlying slowly permeable soils and due to urban run-off to the upper reaches of the catchment. Generally, the catchment of Sketchley Brook may be considered to be relatively impermeable.

The catchment is located within the Midland's regional climate. Most rainfall in the region arrives from the west with Atlantic depressions, much of the West Midlands lies in the 'rain shadow' of the Welsh mountains. This makes the region relatively dry, with the effect enhanced locally by the Severn and Wye valleys³.

² British Geological Survey (2021). UK Soil Observatory Map Viewer. [Source: mapapps2.bgs.ac.uk/ukso/home.html].

³ https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/regional-climates/midlands_-climate---met-office.pdf

Based on the Environment Agency Asset Management website⁴, there are no structural flood defences along the bank of Sketchley Brook, only high ground banks. There is a significant urban extent within the catchment, especially to the upper reaches of the catchment. The lower reaches are generally comprised of grassland and agricultural land use.

1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 12, released September 2023. This contains additional water year for all active peak flow stations in England, Scotland, Wales and Northern Ireland, up to the end of September 2022. It also includes a Period of Record Review of data and metadata for 89 stations in the UK.
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1.4 Gauging stations (flow or level)

(at or very near to the sites of flood estimates)

The study catchment is ungauged. Gauges listed within this section are gauges which were considered as donor catchments.

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km ²)	Type (rated / ultrasonic / level...)	Start of record and end if station closed
River Anker	Anker @ Polesworth	-	28026	368	Crump weir/Velocity-area	01/1966 to present day
River Avon	Avon @ Lilbourne	-	54102	109	Flat V	09/1951 to present day
River Tame	Tame @ Bescot	-	28081	169	Ultrasonic	11/1978 to present day
River Soar	Soar @ Littlethorpe	-	28082	184	Cross-correlation	08/1971 to present day
River Sence	Sence @ South Wigston	-	28086	113	Index velocity	01/1983 to present day

1.5 Data available at each flow gauging station in Table 1.4

Station name	Start and end of NRFA flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed ?	Other comments on station and flow data quality
Anker @ Polesworth	01/1966 to present day	N	Y	Y	N	Crimp profile weir with flanking floodbanks to contain out of bank flows - includes a cableway and downstream recorder. The flow bypasses on the left bank and rejoins downstream after the railway bridge. Multiple ratings accross period of record. Variable drowning makes calculating upper limb difficult. Low modular limit (drowns at approximately 0.6 m [$\sim 8.0 \text{ m}^3/\text{s}$]) and prone to weed growth, causing variable drowning and uncertainty with high flows
Avon @ Lilbourne	09/1951 to present day	N	Y	N	N	Open channel site suffered heavily from weed growth which led to the installation of the flat-v weir. Cableway no longer in use - flow gaugings carried out by waded, remote control or roped ADCP in the same section as the cableway. Weir is situated under a bridge which helps reduce weed growth in the measuring channel and on the weir crest. Due to the known problems with weed at the site, paired with the low modular limit of the weir, a crest tapping tile was added on the weir crest.

Station name	Start and end of NRFA flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Other comments on station and flow data quality
Tame @ Bescot	11/1978 to present day	N	Y	N	N	Ultrasonic installed in 2003 but appeared to be underestimating flows. Replaced with NivuFlow gauge in June 2020. Sensor racks located in same position as previous install, though with a slightly reduced transducer depth so as to minimise impacts of weed and debris accumulation. Low flow data possibly inaccurate, as at best only two paths are in the river. Routine maintenance helps combat silt and weed accumulation within the measurement section.
Soar @ Littlethorpe	08/1971 to present day	N	Y	Y	N	Cross-correlation gauge in a straight reach, replaced an electromagnetic gauge in April 2018. Flood relief channel joins on the right bank just upstream. Bypassed at high flows above 2.4mASD. Banks raised just upstream of station in 1998 to keep flows in bank to a higher stage. Very low velocities at lowest flows may yield unreliable data. Prone to weed growth.
Sence @ South Wigston	01/1983 to present day	N	Y	Y	N	LaserFlow ultrasonic gauge post 2017. Previously electromagnetic gauge set in 1:1 formalised banks and flood embankment 20m downstream of the control. No bypassing - all flow goes through site.
Tabulate any updated or revised flood peak series in the Annex. Give link/reference to any further data quality checks carried out.					-	

1.6 Other data available and how it has been obtained

Type of data	Data relevant	Data available	Source of data	Details
--------------	---------------	----------------	----------------	---------

	to this study?	?		
Check flow gaugings (if planned to review ratings)	Yes	No	-	Study catchment is ungauged
Historic flood data Include chronology and interpretation of flood history in Annex or separate report.			EA	There are no historical records of flooding within the study catchment on the EA WMS ⁵ . In addition, a EA Product 4 provided by the client also states that the EA have no record of flooding in the area.
			BHS Chronology of British Hydrological Events ⁶	There are no historical records of flooding at Hinckley on the CBHE website.
			Previous studies	The SFRA (JBA, 2007) includes information regarding two flooding hotspots in Hinckley. Flooding is also reported along the Sketchley Brook at Coventry Road due to intense urbanisation and the watercourse being culverted in part. The Hinckley Times contained several news articles regarding a flood event of 5 July 2012.
Flow or river level data for events	Yes	No	-	Ungauged watercourse.
Rainfall data for events	No	No	-	No flood event analysis in scope.
Potential evaporation data	No	No	-	No flood event analysis in scope.
Results from previous studies			Hyder (2012) Hazard Mapping Study Hinckley	Flood estimation calculation record available as part of the Hazard Mapping Study Hinckley for Harrow Brook and Sketchley Brook. Final methodology used was the urban extension to the ReFH method.
Other data or information (e.g. groundwater, tides, channel widths, low flow statistics)	-	-	-	-

⁵ Recorded Flood Outlines - data.gov.uk

⁶ <https://www.cbhe.hydrology.org.uk/index.php>

1.7 Hydrological understanding of catchment

Outline the conceptual model, addressing questions such as: - Where are the main sites of interest? - What is likely to cause flooding at those locations? (peak flows, flood volumes, backwater effects, combinations of peaks, groundwater, snowmelt, tides...) - Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? - Is there a need to consider temporary debris dams or NFM features that could collapse?	The primary source of flood risk to the study site is likely to be restriction of flows through culverts and under bridges, driven in part due to increased runoff from impermeable urban areas and urban drainage, especially during times of intense rainfall events during the summer months. Blockage of structures may exacerbate flooding.
Any unusual catchment features to take into account? e.g. - highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% - highly urbanised – seek local flow data; consider method that can account for differing sewer and topographic catchments - pumped watercourse – consider lowland catchment version of rainfall-runoff method - major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully	The study catchment is both small and highly urbanised which will be a limiting factor within this study.

1.8 Initial choice of approach

Is FEH appropriate? (it may not be for extremely heavily urbanised or complex catchments) If not, describe other methods to be used.	The study catchment is small and highly urbanised. However, URBEXT2000 values are <0.6, the recommended limit for FEH methods, and on this basis both the FEH Statistical and ReFH2 methods are appropriate for application.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	Within the urban area, which is located upstream of the area of interest for this study where the proposed development site is located, there are many influences on how the flood hydrograph is routed downstream and hence the resultant peak flow at the site of interest. However, there is a marked difference between the upper and lower catchments of the watercourse with regard to urbanisation and it is considered that the application of sub-catchment / intervening areas for urban areas is not considered necessary as the urban extent is mostly confined to the upstream inflow catchment. Urban extent cannot be discounted which will lend itself to the use of ReFH2. It is not within the scope of the study to obtain and use surface water sewer network details to define sewer catchment boundaries however surface water sewer network information was included within the Hyder (2012) Hazard Mapping Study which will be considered within this study to provide

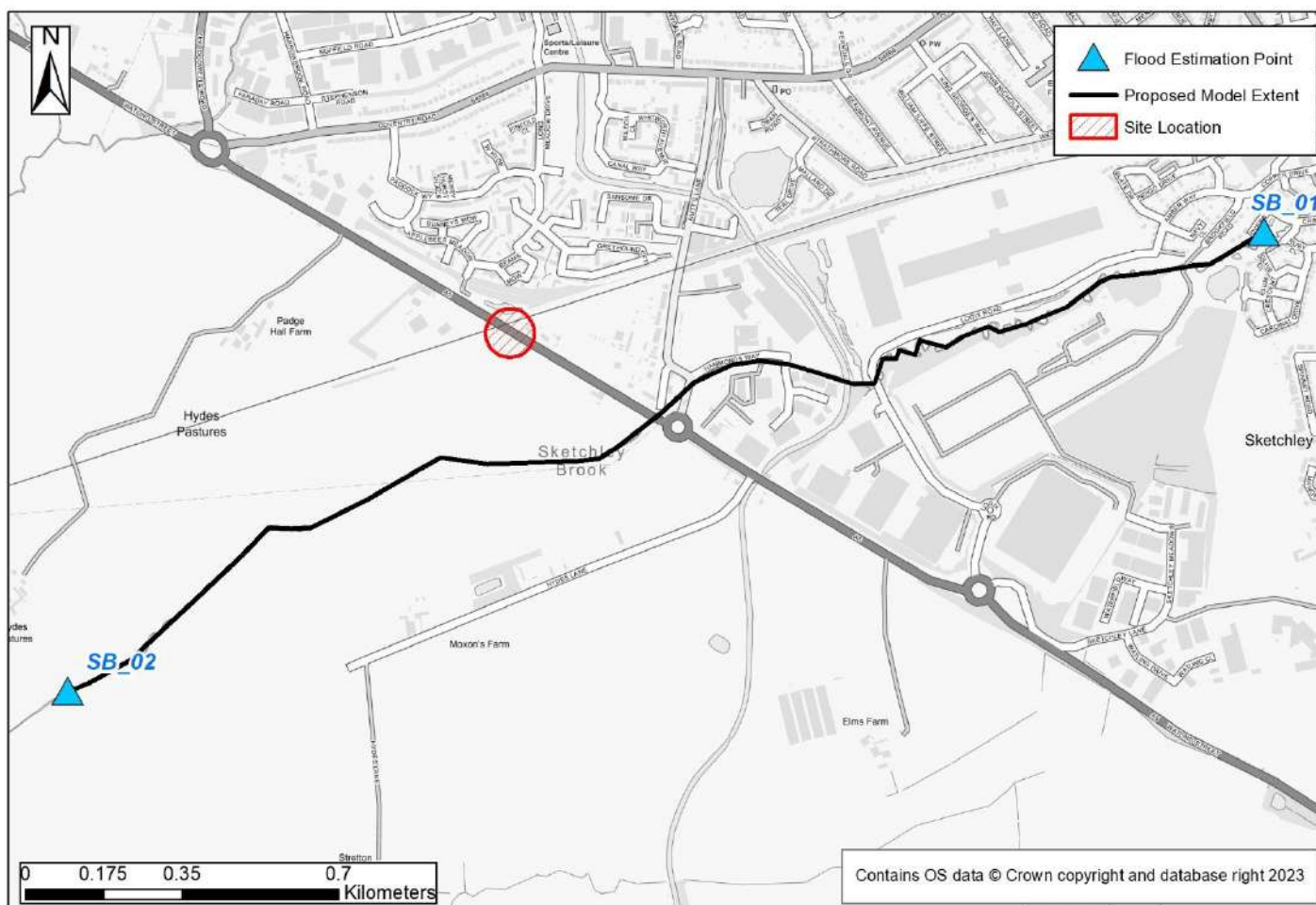
	a greater degree of confidence in flows derived.
Software to be used (with version numbers)	FEH Web Service ⁷ / WINFAP v5 ⁸ / ReFH2.3 calibrated to FEH22 rainfall statistics.

⁷ CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

⁸ WINFAP-FEH v5 © Wallingford HydroSolutions Limited 2018.

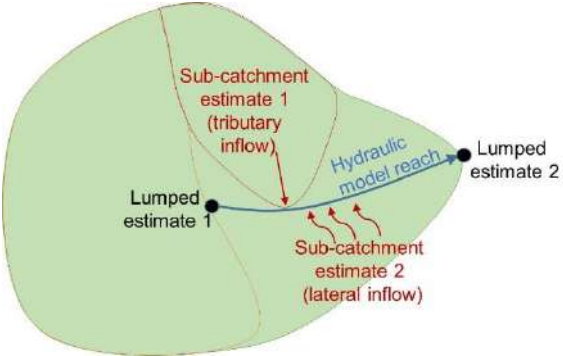
2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.



2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km ²)	Revised AREA if altered
SB_01	L	Sketchley Brook	Model upstream inflow – downstream of Crimson Way	442311	292900	2.44	3.45
SB_02	L	Sketchley Brook	Model downstream check point – Opposite of Hydes Pastures	439643	291876	6.72	7.02

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km ²)	Revised AREA if altered
Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required. Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced. The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.							

2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Values in bold text have been updated from the FEH Web Service values.

Site code	FARL	PROPWET	BFIHOST 19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000 ⁹	FPEXT
SB_01	1.000	0.30	0.448	2.01	26.8	646	0.595	0.093
SB_02	0.983	0.30	0.399	3.32	21.4	647	0.445	0.144

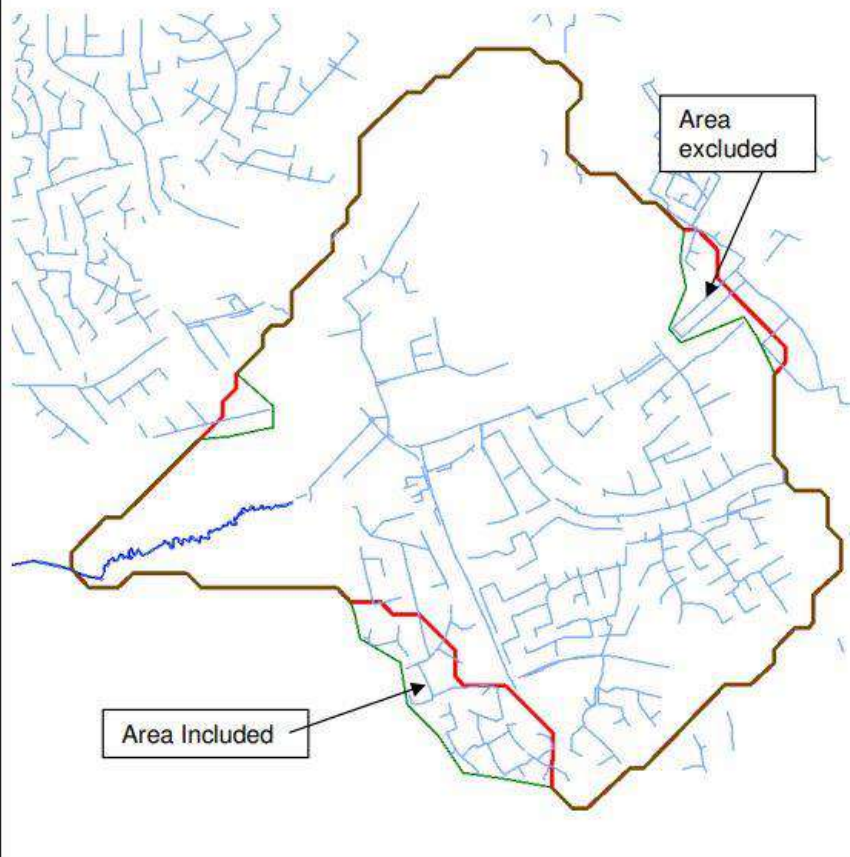
⁹ Updated to current year

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)

An initial review of the catchment boundary was undertaken based on Ordnance Survey mapping and 50m contours. 1m LiDAR data was consulted. Minor modification was required within this study to the lumped catchments to reflect the topographic elevations of the catchment. In addition, the overall catchment extents were modified based on the surface water sewer network information was included within the Hyder (2012) Hazard Mapping Study. Areas that were added or removed from the catchments draining to the defined FEPs defined within the 2012 study were adopted within this study when determining the final catchment extents.

SK_01



Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	A qualitative sense check was carried out for BFIHOST19, FARL and URBEXT2000. The values are considered representative based on the geology and soils detailed in Section 1.2 (BFIHOST19), and Ordnance Survey mapping (FARL and URBEXT2000). Changes were made to the URBEXT2000 values due to changes in the catchment boundary, using the CPRE formula from 2006 CEH report on URBEXT2000. The DPLBAR values were also modified on an area ratio basis. Due to the size of the study catchments the DPLBAR value was modified on an area ratio basis as the standard modification equation is known to produce suspect values for smaller catchments. Catchment descriptors were checked against Cranfield University (2021). Cranfield Soil and Agrifood Institute: Soilscales and British Geological Society (2021). Geology of Britain viewer. Underlying bedrock geology of the catchment is Mercia Mudstone Group - Mudstone. The catchment includes overlying superficial deposits comprising of Glacial sand and gravel and Till. Typical soils across the study catchment are slightly acid loamy and clayey soils with impeded drainage to the upper reaches and slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils. BFIHOST values of c.0.4 are considered representative.
Version of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000
Source of BFIHOST	BFIHOST19 was used in the ReFH2 calculations, since the current release (ReFH2.3) was calibrated using BFIHOST19, and also in the FEH Statistical method, since this has been found to improve the results ¹⁰ .

¹⁰ Griffin, A., Young, A. and Stewart, E. (2019). Revising the BFIHOST catchment descriptor to improve UK flood frequency estimates. Hydrology Research.
 LOY_JBAU_XX_00_RP_HO_0001_S01_P02_JBA FEH calculation record.docx

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m ³ /s) (from catchment descriptors)	Final method	Data transfer					Urban adjust- ment factor (UAF)	Final QMED estimate (m ³ /s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d _{ij} (km)	Moderated QMED adjustment factor, (A/B) ^a	If more than one donor			
						Weight	Weighted ave. adjustment		
SB_01	0.7	DT	28026	8.583	1.070	0.5	1.037	1.755	1.3
			54102	23.683	1.005	0.5			
SB_02	1.4	DT	28026	7.933	1.072	0.5	1.038	1.492	2.2
			54102	24.539	1.005	0.5			
Are the values of QMED spatially consistent?						Yes, QMED increases sensibly moving downstream.			
Method used for urban adjustment for subject and donor sites						WINFAP v4 ¹¹			
Parameters used for WINFAP v4 urban adjustment if applicable									
Impervious fraction for built-up areas, IF			Percentage runoff for impervious surfaces, PR _{imp}			Method for calculating fractional urban cover, URBAN			
0.3			70%			From updated URBEXT2000			
Notes									
Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).									
The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is: (A/B) ^a × QMED _{initial} × UAF									
Important note on urban adjustment									
The method used to adjust QMED for urbanisation published in Kjeldsen (2010) ¹² in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.									

¹¹ Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

¹² Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Include a map if necessary. Note that donor catchments should usually be rural.	A number of potential donor catchments for this study were identified using the NFRA website and the 'Estimating QMED by data transfer' tool which is available in WINFAP-FEP5 as there are no donor catchments available within the study catchments. Two were taken forward for further consideration as a potential donor catchment: • 28026 - Anker @ Polesworth • 54102 - Avon @ Lilbourne The previous study considered a number of stations which fell within a pre-defined search area but due to disparity in catchment size and other key descriptors and/or the degree of urbanisation these were also ruled out as potential donors. It was concluded that no suitable donor sites for use in data transfer to the Hinckley catchment were available. 28026 was identified as a potential suitable donor due to a combination of similarity in descriptors and proximity. 54102 was identified as a potential suitable donor due to similarity of SAAR and SPRHOST values. It is acknowledged that 54102 differs to the site in terms of FARL (0.91) however it was felt that the study site would benefit more from the use of two donor sites over the use of just 28026 on its own. LIT-11832 Flood Estimation Guidelines (2023) states that data transfer should occur in all cases where QMED is estimated at an ungauged site. <i>"It is not essential for donor and subject sites to be similar in catchment area, BFIHOST and other catchment descriptors included in the QMED regression equation. However, in view of the uncertain relationship between BFIHOST and runoff, some analysts prioritise donors that are more similar in geology or soil type. You should consider using more than one donor."</i> Both catchments were identified by NRFA and WINFAP 5 as potentially suitable due to a mixture of proximity and on hydroclimatological similarities to the study catchments. Upon assessment of catchments descriptors, it was considered that a combination of both donors would be a suitable donor catchment.
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3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjustment for climatic variation ?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjustment ratio (A/B) *
28026	Closest hydroclimatological similarities to subject site	AM	No	48.2	37.34	1.187
54102	Closest hydroclimatological similarities to subject site	AM	No	13.6	13.27	1.019
28081	NA – not chosen due to difference in catchment characteristics (FARL, SAAR, SPRHOST and URBEXT2000)	-	-	37.9	23.11	0.889
28082	NA – not chosen due to difference in catchment characteristics (SPRHOST and URBEXT2000)	-	-	16.3	18.59	0.835
28086	NA – not chosen due to difference in catchment characteristics. (BFIHOST and URBEXT2000)	-	-	19.6	18.38	1.032
* After application of separate 'de-urbanisation' factors to the observed QMED values.						

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group. All FEP's will use the same pooling group, derived from the catchment descriptors for SB_02. Catchment descriptors all FEP's are relatively similar and it is unlikely that a pooling group derived for SB_01 would differ to a pooling group derived for SB_02. In addition, LIT 11832 Flood Estimation Guidelines (2023) states that it is good practice to apply one pooling group to multiple points along a watercourse to promote spatial consistency.

Name of group	Site code from whose descriptor s group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
SB_02 'Small Catchment' Pooling ¹³	SB_02	No	Removed: 26016 (Gypsy Race @ Kirby Grindalythe) and 26014 (Water Forlornes @ Driffield): Very high BFIHOST in comparison to site (> 0.9) Included: 36004 (Chad Brook @ Long Melford)	L-CV: 0.286, L-SKEW: 0.223.
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

13 Small Catchment pooling method applied via WINFAP v5

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (3.4)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
SB_01	P	SB_02 'Small Catchment' Pooling	KAP3 smallest absolute z-value, although GL and GEV also give acceptable fits.	WINFAP-FEHV5 urban adjustment	Location: 0.943 Scale: 0.244 Shape: -0.257	3.31
SB_02						

Notes

Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis

A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.

Urban adjustments are all carried out using the method of Kjeldsen (2010).

Growth curves were derived using the procedures from Science Report SC050050 (2008).

3.6 Flood estimates from the statistical method

Site code	Flood peak (m ³ /s) for the following AEP (%) events					
	50	3.3	1	1 + 22% climate change allowance (Central)	1 + 30% climate change allowance (Higher)	0.1
SB_01	1.3	3.2	4.3	5.2	5.6	6.9
SB_02	2.2	5.4	7.1	8.7	9.3	11.6

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Parameters for ReFH2 model

In accordance with research findings, all catchments with URBEXT2000 up to 0.30 were modelled as if they were rural. Research on flood estimation in small catchments¹⁴ found that flood frequency estimates on such catchments were more accurate if the catchment was treated as rural. This reflects the difficulty of generalising the complex and locally-specific effects that urban development has on flood flows. EA Flood Estimation Guidelines LIT 11832 (2023) states that the FEH Statistical method or ReFH2 methods can be applied to urbanised catchments with an URBEXT2000 value up to 0.6¹⁵. A winter storm rainfall depth, Cini and initial baseflow values and storm profile should be used for all catchments, unless:

- URBEXT2000 $\geq$ 0.30;
- or URBEXT2000 $\geq$ 0.15 and BFIHOST19 $\geq$ 0.65

Therefore a Summer, Urban Profile was used.

As the catchment extent within Section 2 was modified to represent the urban sewer area which is contained within the catchment, based on information provided within the 2012 study, sewer exports outside of the catchment have not been considered further.

All catchments					Only extremely heavily urbanised catchments
Site code	Method	C _{max} (mm)	Tp _{rural} (hours)	BL (hours)	Area of catchment modelled as urban (km ²)
SB_01	CD	366.4	3.97	38.47	-
SB_02	CD	322.61	5.68	40.01	-
Link to details of any lag or flood event analysis		Not within scope			
Version of the ReFH2 model applied		ReFH2.3 using the water balance option. This treats BR (baseflow recharge) as a state variable rather than a parameter, setting it automatically in order to conserve volume. The values of BR vary with return period and so are not reported here.			
Parameters for urban runoff model		The impervious fraction of urban areas, IF, was kept at its default of 0.4. While the catchments were modified to account for the sewer extent provided within the 2012 study, the sewer extents largely followed the topographic profile of the catchment. Default parameters were retained within this study as there is uncertainty in using 2012 sewer data to update default parameters. The impervious runoff factor, IRF, (which can also be interpreted as the fraction of the impervious surface that is positively drained) was kept at its default of 0.7. The depression storage was kept at its default of 0.5mm. Tp for runoff from areas modelled as positively drained was calculated as 0.75 times Tp_{rural}.			
Methods: OPT: Optimisation from fitting to observed flow data, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)					

¹⁴ Stewart, Lisa, Duncan Faulkner, Giuseppe Formetta, Adam Griffin, Tracey Haxton, Ilaria Prosdoci, Gianni Vesuviano and Andy Young (2021). Estimating flood peaks and hydrographs for small catchments (Phase 2). Report – SC090031/R0, Environment Agency.

¹⁵ Environment Agency (2012) Estimating flood peaks and hydrographs for small catchments: Phase 1 and Phase 2. LOY_JBAU_XX_00_RP_HO_0001_S01_P02_JBA FEH calculation record.docx

4.2 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
SB_01	Urban	Summer	06:15:00
SB_02	Urban	Summer	06:15:00
All FEP points were run to the ReFH2 critical storm duration of SB_01 due to the urban extent of the inflow catchment (6.25hr) to provide consistency between the FEP's. For modelling purposes, the critical storm duration used for peak flows and design hydrographs will be the design storm duration for SB_01.			

4.3 Flood estimates from the ReFH2 method

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Site code	Flood peak (m ³ /s) for the following AEP (%) events					
	50	3.3	1	1 + 22% climate change allowance (Central)	1 + 30% climate change allowance (Higher)	0.1
SB_01	1.8	3.6	4.6	5.6	5.9	7.9
SB_02	2.7	5.4	6.8	8.3	8.8	11.8

6 Discussion and summary of results

6.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak	
	Return period 2 years	Return period 100 years
	ReFH2	ReFH2
SB_01	1.39	1.07
SB_02	1.23	0.95

6.2 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	Flows derived through the application of the ReFH2 model were compared with those derived from the FEH Statistical method. Flows derived from the ReFH2 methodology are smaller than flows derived from the FEH Statistical method for all design events and for all lumped catchments. For SB_01, the percentage difference in flows decreases as the frequency of the flood event increases and, for the 2-year event, ReFH2 flows are 39% greater than the flows derived from FEH Statistical. The catchment considered within this study is small, urbanised, and ungauged and, as such, all estimated design flows carry appreciable uncertainty. The urbanised nature of the catchments, especially to the upper reaches of the model, lends itself to the application of the ReFH2 peak flows for a summer, urban profile.
How will the flows be applied to a hydraulic model? If relevant. Will model inflows be adjusted to achieve a match with lumped flow estimates, or will the model be allowed to route inflows?	Catchment flows will be distributed along the study reach at locations where flow points have been identified within Figure 2.1. For modelling purposes, hydrographs were obtained using the ReFH2 method to storm duration of 06:15:00hr (CSD for SB_01). During the modelling phase of this study, if it is found that a lateral inflow is required, flows for the lateral area (c. 3.5km²) will be derived by using an area ratio method from the flows derived for SB_02. The hydrograph adopted for the lateral areas will be the design hydrograph for SB_02.

6.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions are: The catchment boundaries, descriptors and information adopted from the previous study are representative; The pooling group used to derive peak flow estimates is representative of the subject catchment; Design hydrographs generated are representative of those that would be observed during typical flood events; It is assumed that the sewer extents supplied within the 2012 study are representative of the current sewer extent; Use of KAP3 distribution in pooling group assessment is
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	assumed to be preferable to the other distributions identified by WINFAP 5 due to its z-value.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	The main limitation for this study is the absence of flow gauge data for Sketchley Brook with which to improve peak flow estimates. As flood generation on urban catchments is so sensitive to local circumstances it is not possible to obtain a reliable estimate of the flood frequency curve using generalised methods. There is no substitute for obtaining local data. The scope of the study is also a limitation as it was not possible to assess the surface water sewer network for the purposes of sub-catchment definition or to undertake lag analysis to improve the ReFH2 Tp model parameter. The catchments have URBEXT2000 values close to 0.6, the recommended limit for the application of the FEH methods. This has been accepted as a necessary limitation due to the scope of the study. It should be noted that alternative methods also have drawbacks.
Give what information you can on uncertainty in the results, e.g. confidence limits from Kjeldsen (2014).	No published methods of calculating confidence intervals exist for ReFH hydrological models; therefore, the uncertainty for each of these watercourses is difficult to quantify. The uncertainty will depend on many factors, for example, how unusual the study catchment is relative to the pooling group and donor catchment, and the uncertainty in flow measurement at other gauges. The Environment Agency Flood Estimation Guidelines present confidence limits for Statistical method design flows at ungauged sites. There are confidence intervals for rural catchments ($URBEXT2000 < 0.03$) and moderately urbanised catchments ($0.03 \leq URBEXT2000 < 0.15$). The 95% confidence limits for a 1% AEP flood estimate without donor adjustment of QMED are: - Rural catchments: 0.45 – 2.23 times the best estimate - Moderately urbanised catchments: 0.33 – 3.01 times the best estimate Confidence intervals for heavily urbanised catchments ($URBEXT2000 > 0.15$) are not provided because there are not enough suitable catchments with flood peak data to provide reliable statistics. It may be assumed that the confidence intervals will be somewhat wider than those for moderately urbanised catchments.
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	Results are suitable for the purposes of the current study. If used in other studies, a review of the approach and subsequent results is recommended as a minimum.
Give any other comments on the study, e.g. suggestions for additional work.	Confidence could be improved through installation of a flow gauge on Sketchley Brook, to provide data suitable for use in design flow estimation.

6.4 Checks

Are the results consistent, for example at confluences?	Yes, results are considered sensible in that they increase with downstream distance where applicable.
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What do the results imply regarding the return periods of floods during the period of record?	No data is available in regards to flood events applicable to the site. No flow gauges are available within the study catchment, therefore no comparison with previous events can be undertaken at this stage.												
What is the range of 100-year growth factors? Is this realistic?	The 1% AEP growth factor for each of the methods are: - FEH Statistical: 3.31 - ReFH2: 2.54 The typical range is 2.1 to 4.0 (based on FSR regional growth curves) therefore the 1% AEP growth factor for all FEP's are inside the typical range for both flow estimation methodologies.												
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1%/ 1% AEP event growth factor for each of the methods are: - FEH Statistical: 1.62 - ReFH2: 1.73-1.74												
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	The flood estimation calculation record is available as part of the Hyder (2012) Hazard Mapping Study Hinckley for Harrow Brook and Sketchley Brook. Final methodology used was the urban extension to the ReFH method. Two flood estimation points were used along as part Sketchley Brook – SK_01 which is located c.1km downstream of SB_01 and 1.8km upstream of SB_02. <table><tr><td></td><td>100</td><td>1000</td></tr><tr><td>SB_01</td><td>4.56</td><td>7.89</td></tr><tr><td>SK_01</td><td>5.97</td><td>11.64</td></tr><tr><td>SB_02</td><td>6.76</td><td>11.80</td></tr></table> Flows obtained from ReFH2 for this current study are comparable to the flows derived from ReFH1 in 2012. ReFH2 has superseded ReFH1 and is considered to be the more reliable method. As the current study utilises the latest datasets, methods and guidance, results derived for this study are preferred.		100	1000	SB_01	4.56	7.89	SK_01	5.97	11.64	SB_02	6.76	11.80
	100	1000											
SB_01	4.56	7.89											
SK_01	5.97	11.64											
SB_02	6.76	11.80											
Are the results compatible with the longer-term flood history?	N/A – There is no catchment flow gauge data and very little / no historical flooding information related to the proposed development site.												
Describe any other checks on the results	-												

6.5 Final results

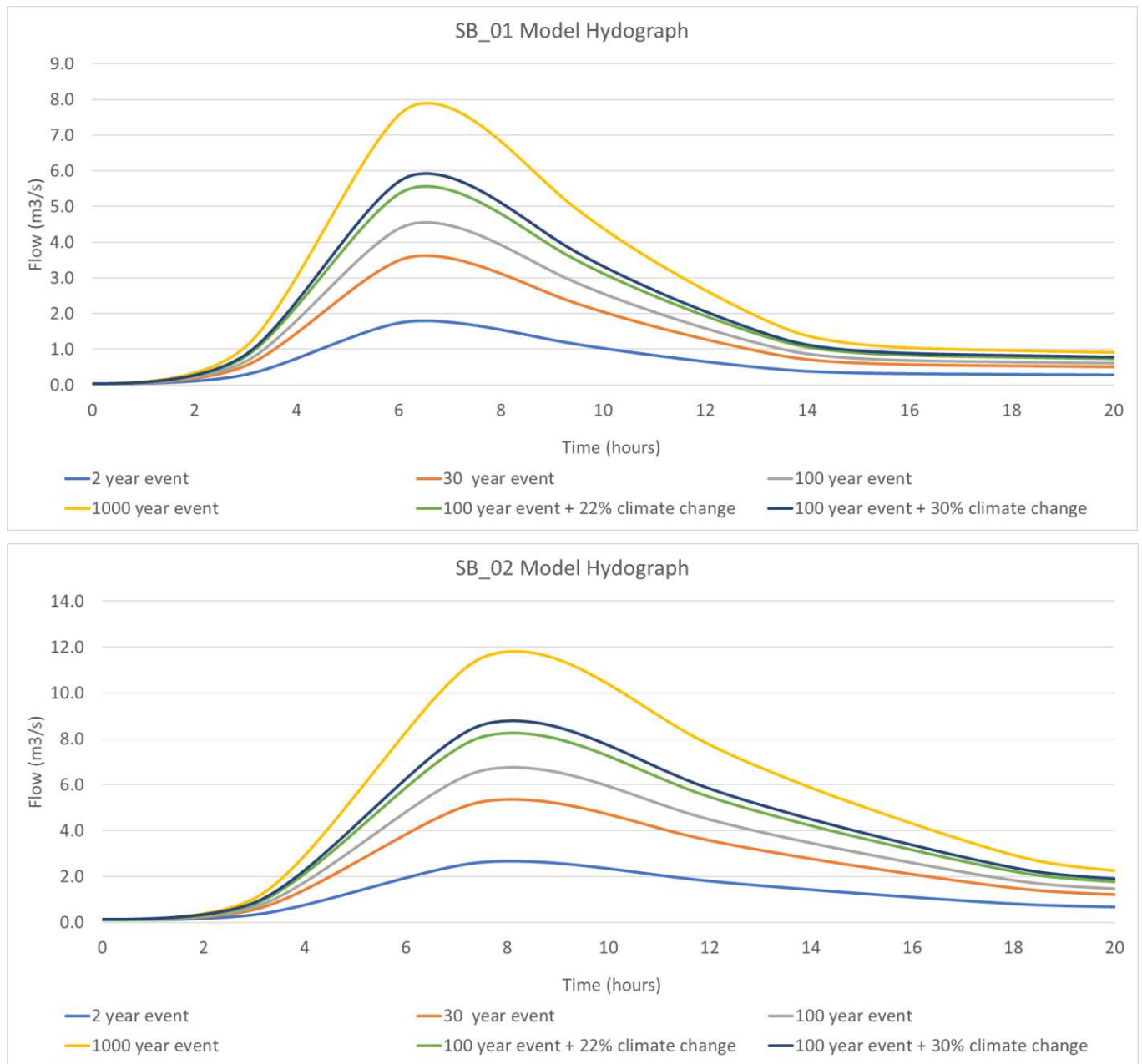
Site code	Flood peak (m ³ /s) for the following AEP (%) events					
	50	3.3	1	1 + 22% climate change allowance (Central)	1 + 30% climate change allowance (Higher)	0.1
SB_01	1.8	3.6	4.6	5.6	5.9	7.9

SB_02	2.7	5.4	6.8	8.3	8.8	11.8
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If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	Annex B
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7 Annex A – Pooling Groups

8 Annex B – Design Hydrographs



Offices at

Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Limerick
Newcastle upon Tyne
Newport
Peterborough
Saltaire
Skipton
Tadcaster
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Registered in England 3246693

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
ISO 45001: 2018



F Sensitivity Analysis

F.1 Fluvial sensitivity analysis

F.1.1 Sensitivity to roughness

Figure E 1 shows the impact in peak water level when 1D and 2D roughness is adjusted by +20% during the 100-year event. This shows the model is not sensitive to changes in roughness, with the greatest impact of 0.16m found at node SKBRx_10. Despite a small number of river section roughness values being based on photographic evidence in the 1D, the majority of the roughness values have been derived from the original 2013 model. Roughness values used within the 2D domain of this model are considered to be appropriate.

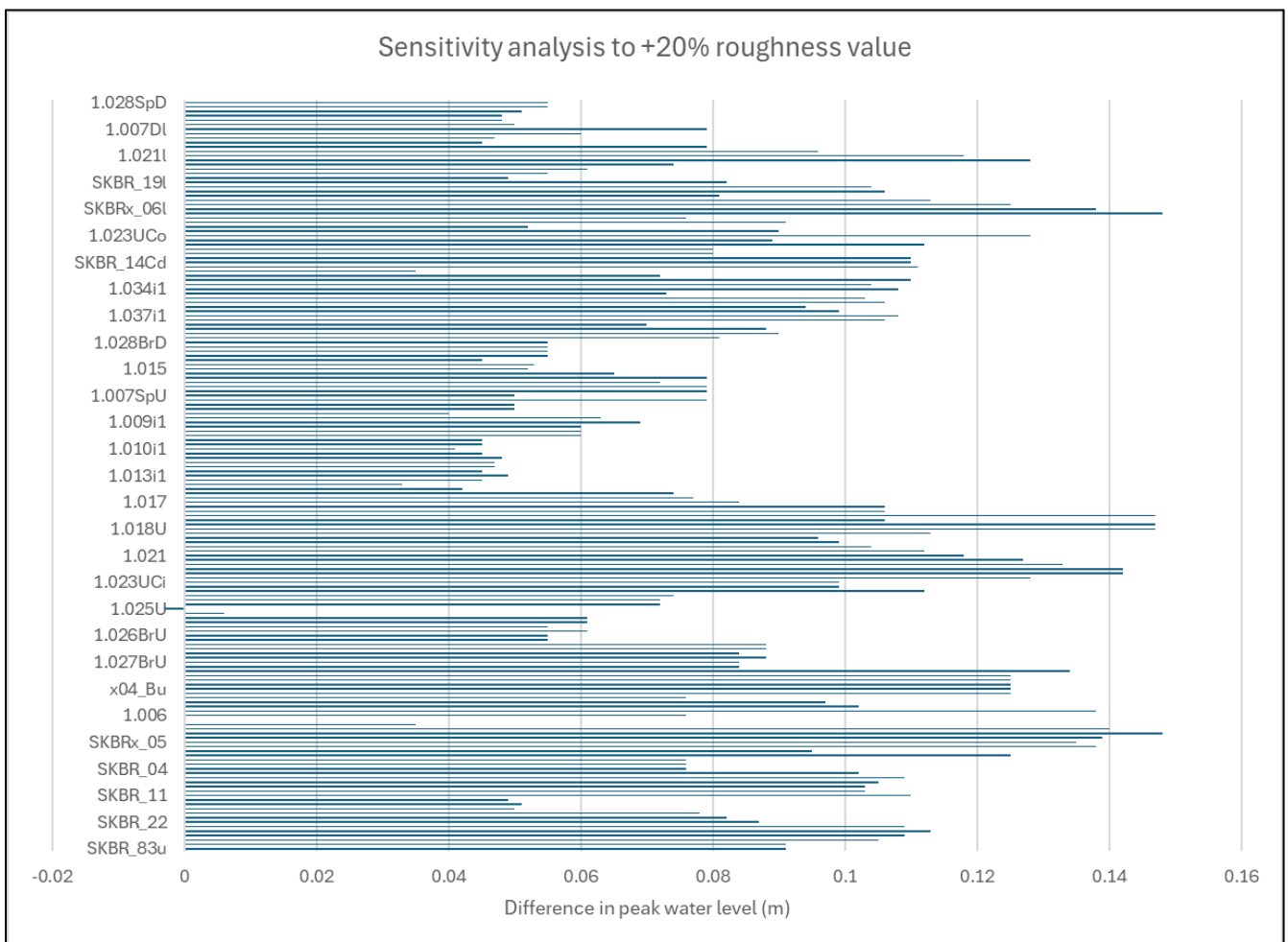


Figure E 1: Fluvial sensitivity analysis for +20% roughness

F.1.2 Sensitivity to downstream boundary conditions

Figure E 2 shows the impact in peak water level when a 250mm increase in values at the downstream boundary is applied to the 1D downstream boundary during the 100-year

event. This impact shows the model is not sensitive to changes in the downstream boundary conditions, with the greatest impact of 0.25m being found at node 1.006.

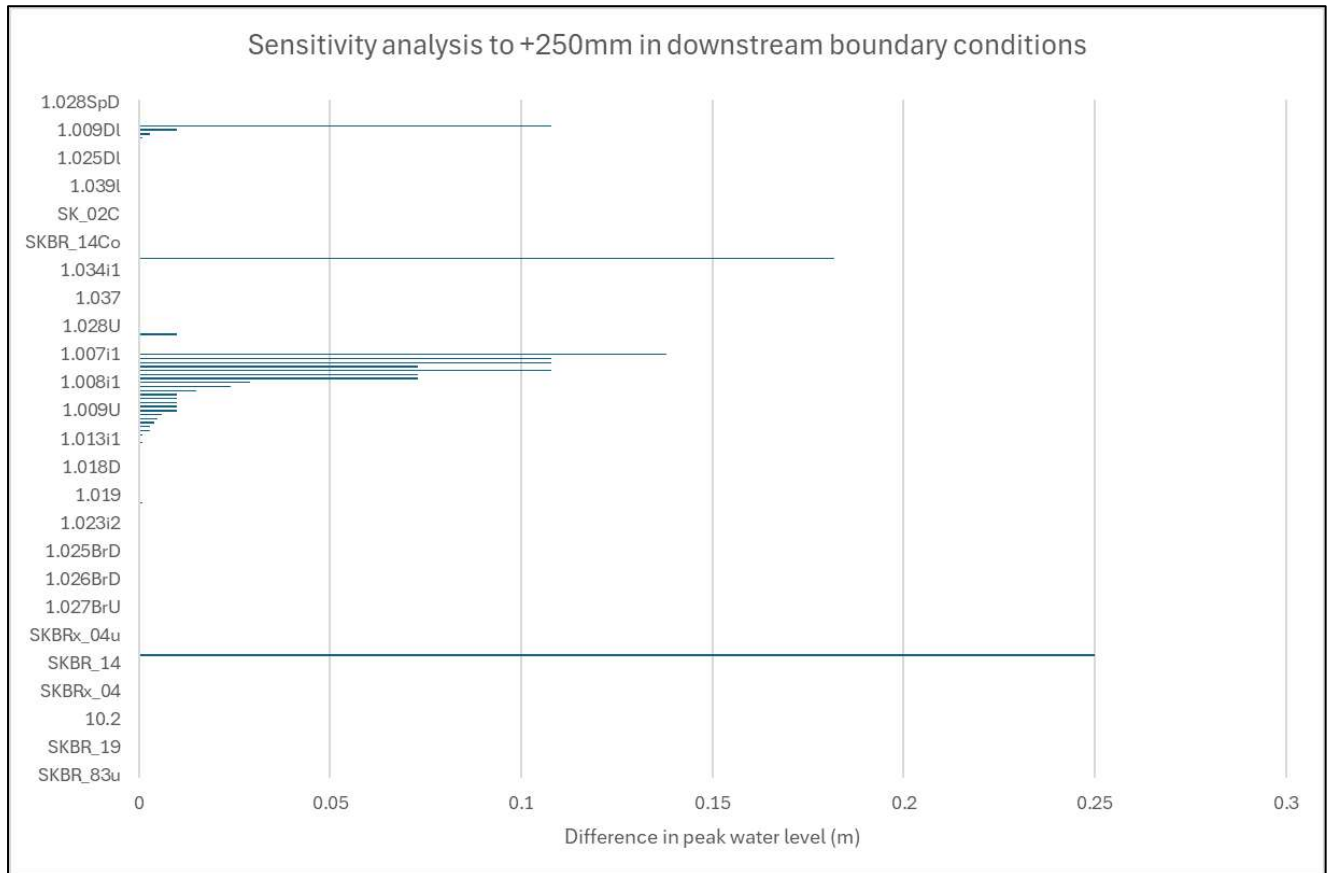


Figure E 2: Fluvial sensitivity analysis for +250mm increase at the downstream boundary

F.1.3 Sensitivity to flow

Figure E 3 shows the impact in peak water level when 1D flow is adjusted by +20% during the 100-year fluvial flood event. The greatest impact of 0.46m is found at node SKBRx_04u. This shows the model is sensitive to changes in flow as the impact is disproportionate. However, the hydrology used within the model follows best practice and is therefore considered to be appropriate.

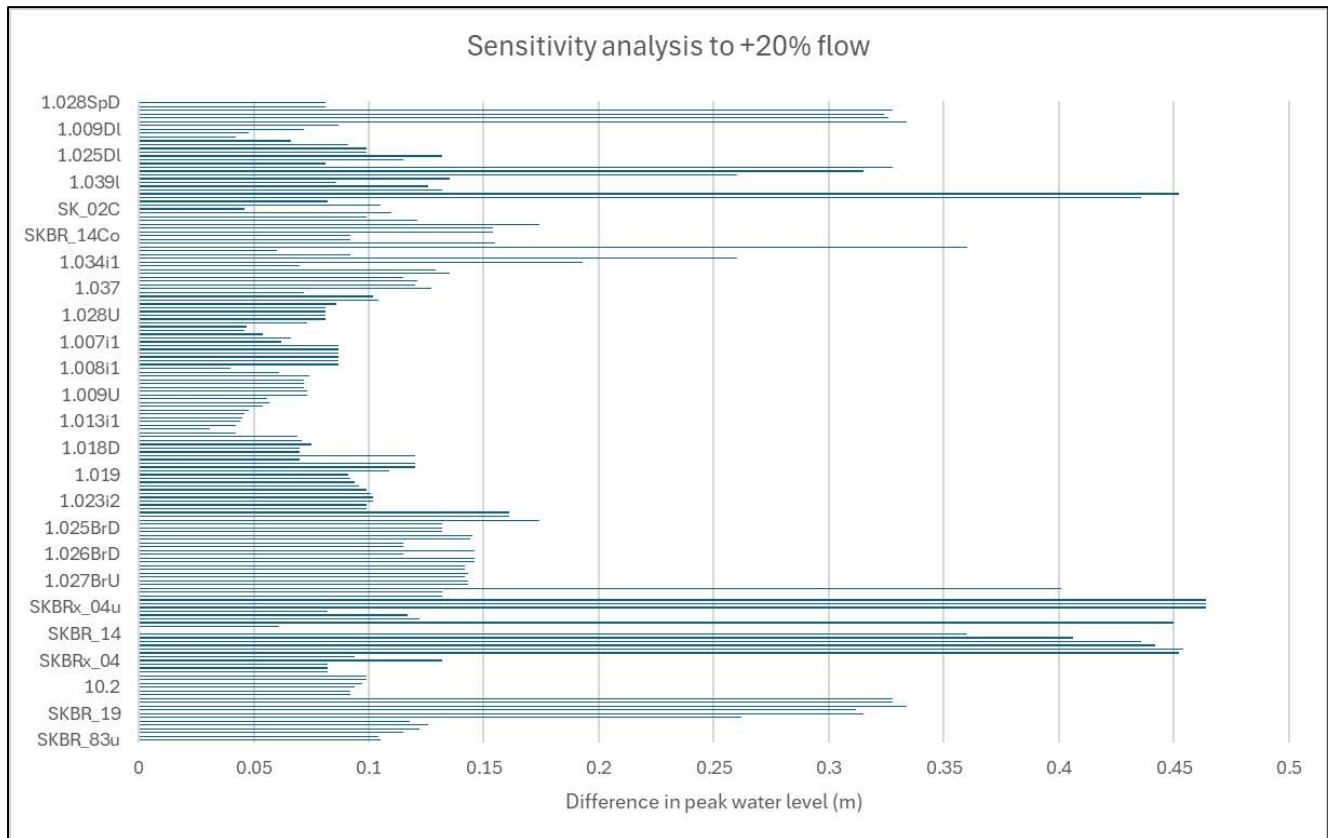


Figure E 3: Fluvial sensitivity analysis for +20% flow

F.2 Surface water sensitivity analysis

F.2.1 Sensitivity to roughness

Figure E 4 shows the impact in peak water level when 1D and 2D roughness is adjusted by +20% during the 100-year event. This shows the model is not sensitive to changes in roughness, with the greatest impact of 0.13m found at node 1.009i1. Despite a small number of river section roughness values being based on photographic evidence in the 1D, the majority of the roughness values have been derived from the original 2013 model. Roughness values used within the 2D domain of this model are considered to be appropriate.

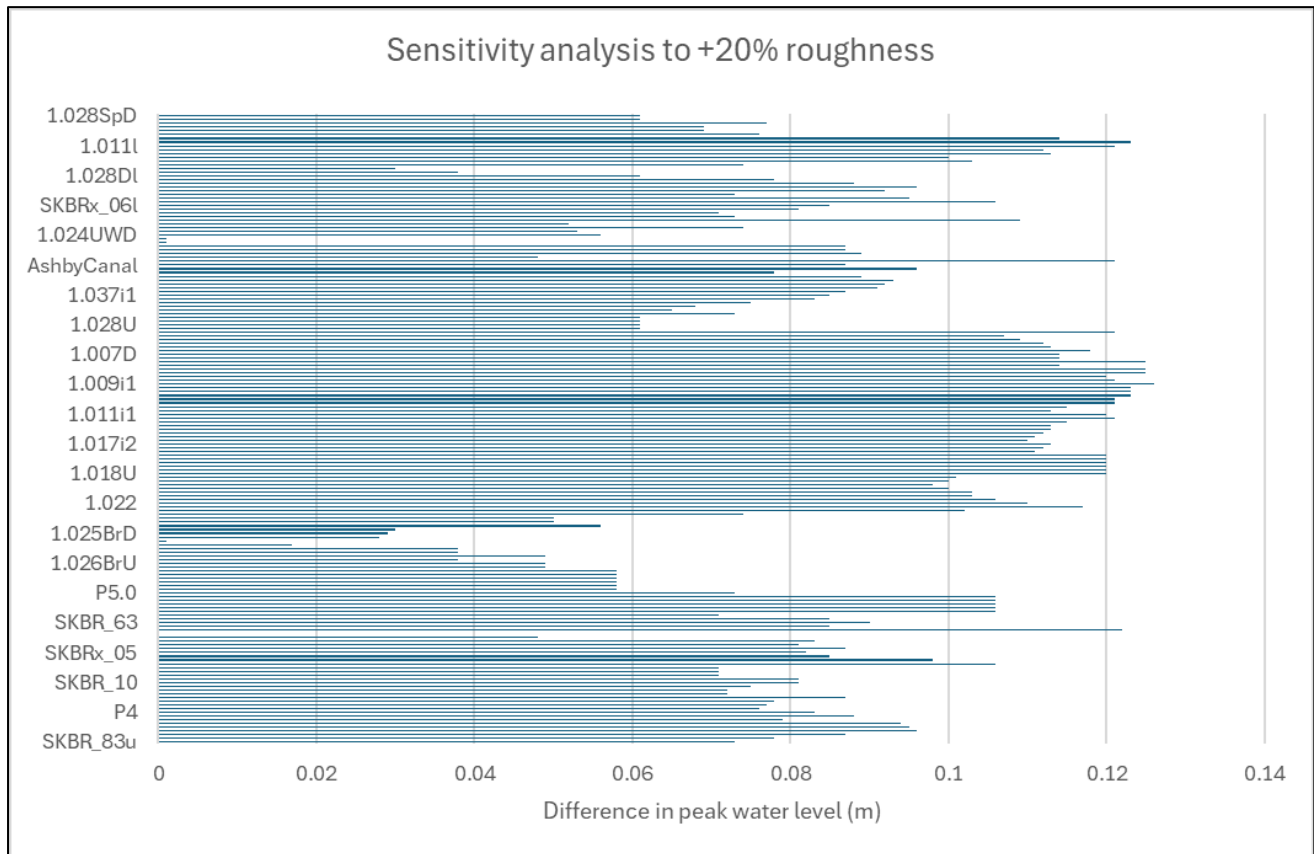


Figure E 4: Surface water sensitivity analysis for +20% roughness

F.2.2 Sensitivity to flow

Figure E 5 shows the impact in peak water level when 1D flow is adjusted by +20% during the 100-year fluvial flood event. The greatest impact of 0.04m is found at nodes 1.009SpU, 1.009U and 1.009BrU. This shows the model is not sensitive to changes in flow. The hydrology used within the model follows best practice and is therefore considered to be appropriate.

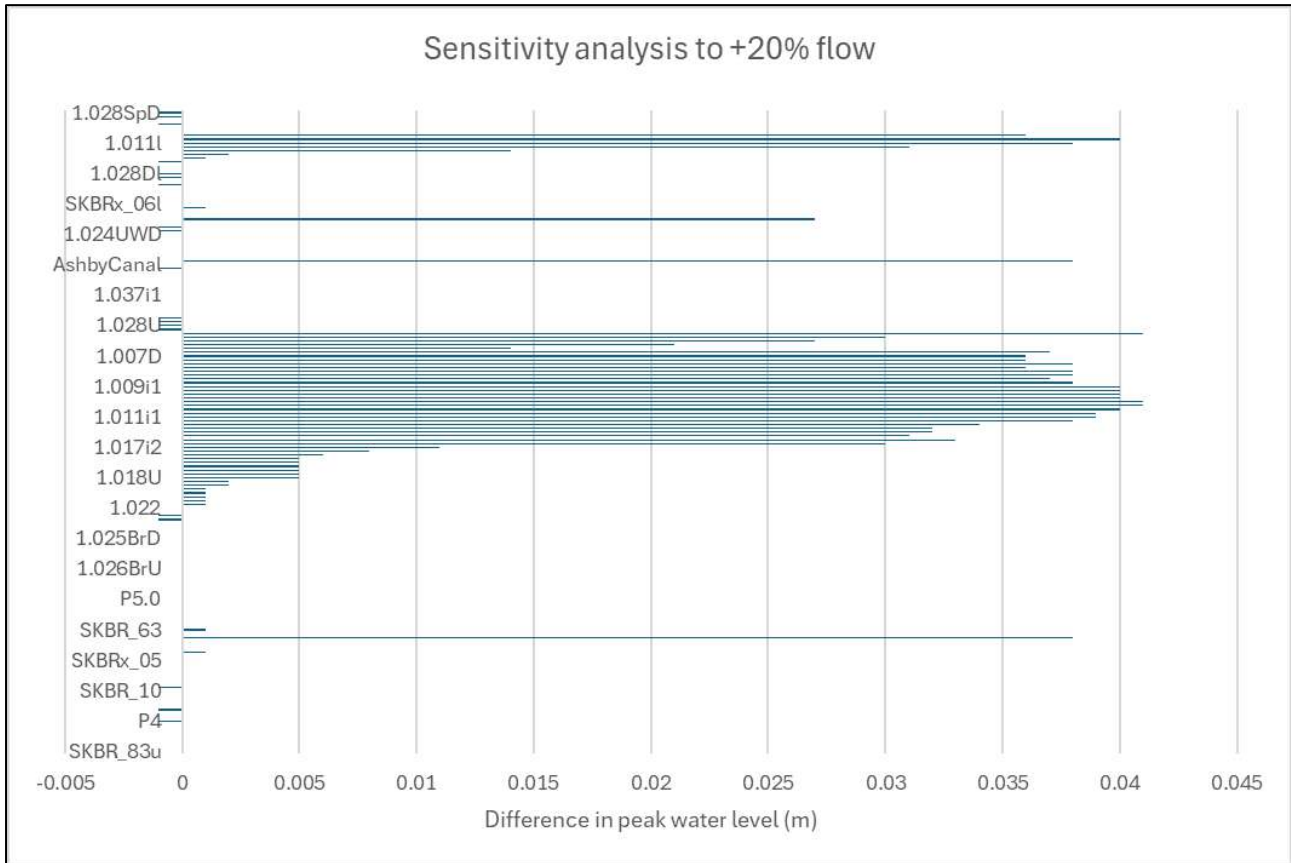
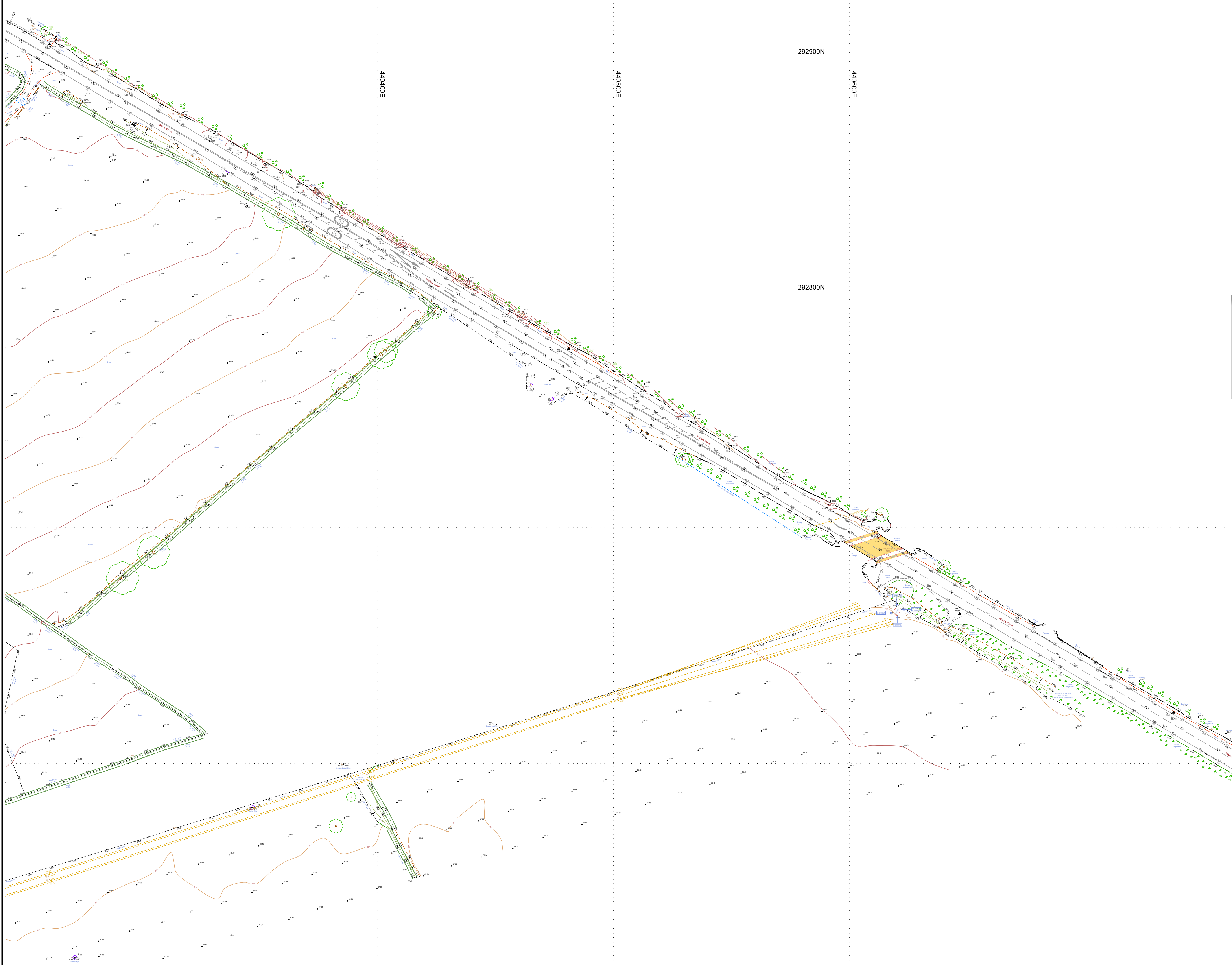


Figure E 5: Surface water sensitivity analysis for +20% flow

G Topographic Survey Data



Station	Easting (m)	Northing (m)	Level (m)
GH1	440480.925	292775.932	91.248
GH2	440260.838	292905.057	94.871
GH3	440143.358	292789.665	94.907
GH4	440075.276	292749.612	94.600
GH5	440033.384	292709.106	94.382
GH5A	439923.402	292668.592	94.179
GH5B	439702.699	292685.715	91.345
GH5C	439649.086	292874.399	90.637
GH6	440155.261	292968.854	92.876
GH7	440003.277	293048.741	91.353
GH7A	439978.239	293121.464	90.854
GH8	439918.721	293077.164	90.376
DH1	439564.829	292962.598	88.859
DH2	439708.261	293075.060	88.879

Surveyed Buildings

No scale factor has been applied to the survey therefore the coordinates shown are arbitrary & not true O.S. Coordinates which have a scale factor applied.

Legend:

[illegible]

5	08.03.23	Levels added waiting street	SA	GH1634
4	24.06.21	Additional topo	JK2	GH1092
3	01.05.20	Drainage info added	JK2	GH737
2	August 2019	Survey Extension	SA	GH576
1	April 2019	Western Area Survey	BG	GH488
Rev	Date	Description	Drawn	Q Ref



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CLIENT
**Mountpark Properties
Ltd**

PROJECT
Watling Street (A5),
Hinckley,
LE10 3ED

TITLE	Topographical Survey
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SCALE A0@ 1: 1250	DATE 07-18.02.19
DRAWN MR	QUALITY REF GH4539

Level datum	See note
Grid orientation	See note
Job number	32726

Drawing No.	Rev.
32726_T	5

Comments	This plan should only be used for its original purpose. Greenhatch Group accepts no responsibility for this plan if supplied to any party other than the original client. All dimensions should be checked on site prior to design and construction. Drainage information (where applicable) has been visually inspected from the surface and therefore should be treated as approximate only.
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