

ENVIRONMENT

A R Cartwright (Construction) Ltd
Chapel Lane
Wetherley
Flood Risk Assessment

ENVIRONMENT

A R Cartwright (Construction) Ltd
Chapel Lane
Witherley
Flood Risk Assessment

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

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

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

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

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

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

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

October 2021

DOCUMENT ISSUE RECORD

Document Number:	ARC100-BWB-EWE-XX-RP-EN-0002_FRA
BWB Reference:	BMW-2465-FRA

Revision	Date of Issue	Status	Author:	Checked:	Approved:
P05	12/10/2021	S2	Alex Petrakis BSc. (Hons)	Max Brambani BSc (Hons) PgCert MCIWEM	Claire Gardner BSc (Hons) MSc MCIWEM C.WEM

Notice

All comments and proposals contained in this report, including any conclusions, are based on information available to BWB Consulting during investigations. The conclusions drawn by BWB Consulting could therefore differ if the information is found to be inaccurate or misleading. BWB Consulting accepts no liability should this be the case, nor if additional information exists or becomes available with respect to this scheme.

Except as otherwise requested by the client, BWB Consulting is not obliged to and disclaims any obligation to update the report for events taking place after: -

- (i) The date on which this assessment was undertaken, and
- (ii) The date on which the final report is delivered

BWB Consulting makes no representation whatsoever concerning the legal significance of its findings or the legal matters referred to in the following report.

All Environment Agency mapping data used under special license. Data is current as of October 2021 and is subject to change.

The information presented, and conclusions drawn, are based on statistical data and are for guidance purposes only. The study provides no guarantee against flooding of the study site or elsewhere, nor of the absolute accuracy of water levels, flow rates and associated probabilities.

This document has been prepared for the sole use of the Client in accordance with the terms of the appointment under which it was produced. BWB Consulting Limited accepts no responsibility for any use of or reliance on the contents of this document by any third party. No part of this document shall be copied or reproduced in any form without the prior written permission of BWB

EXECUTIVE SUMMARY

This Flood Risk Assessment (FRA) has been prepared in accordance with the requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance. It has been produced on behalf of A R Cartwright (Construction) Ltd in respect of a planning application for residential development off Chapel Lane, Witherley (approximate grid ref: SP329975).

This report demonstrates that the proposed development is at an acceptable level of flood risk, subject to the recommended flood mitigation strategies being implemented.

The dominant flood risk source to the wider site is fluvial, from an unnamed southern tributary of the Witherley Brook. This was initially modelled by BWB in 2016 and has since been updated in 2021 to inform this planning submission. Amendments to the hydraulic model were made to address updates to hydrological methods, modelling software and climate change guidance.

The 2021 model outputs demonstrate that the flood risk posed from this watercourse is controlled by the capacity of the Atterton Lane culvert, which is located downstream of the site. This means that flooding during the design event flood (1 in 100yr+22% climate change) is extensive in the local area.

Accordingly, the application site and proposed development has been sequentially arranged so that it is located entirely outside of the design event floodplain. This ensures that the development will be safe for its lifetime, including the impacts of climate change, and that it will not increase flood risk elsewhere. This is of particular importance given that the Environment Agency have provided historical records that demonstrates that the downstream settlement of Witherley has previously flooded. Furthermore, finished floor levels will be raised to a minimum level of 71.40mAOD to provide 600mm freeboard above the design flood level. This will also ensure that 440mm of freeboard is provided should the Atterton Lane culvert become completely blocked during the 1 in 100yr+22% climate change event.

The site access/egress route has been reviewed in detail due to historical flooding of the highway, particularly at the junction of Chapel Lane/Atterton Lane. Whilst the route becomes inundated for events above and including the 1 in 100yr event, the low velocities mean that the road should be passable for emergency service vehicles as the Flood Hazard rating is largely below 0.75.

In compliance with the requirements of the NPPF, and subject to the mitigation measures proposed, the development could proceed without being subject to significant flood risk. Moreover, the development will not increase flood risk to the wider catchment area subject to suitable management of surface water runoff discharging from the site.

CONTENTS

EXECUTIVE SUMMARY	III
1. INTRODUCTION.....	1
Sources of Data	1
Existing Site	2
Proposed Development	3
2. FLOOD RISK PLANNING POLICY	5
National Planning Policy Framework.....	5
Flood Map for Planning	5
The Design Flood.....	6
Climate Change.....	7
Strategic Flood Risk Assessment	8
Preliminary Flood Risk Assessment.....	8
Local Flood Risk Management Strategy.....	9
Other Relevant Policy and Guidance	9
3. POTENTIAL SOURCES OF FLOOD RISK	11
Fluvial Flood Risk.....	12
Coastal/Tidal Flood Risk	14
Flood Risk from Canals	14
Groundwater Flood Risk.....	14
Flood Risk from Reservoirs & Large Waterbodies	15
Pluvial Flood Risk	16
Historical Instances of Flooding in the Region.....	18
Access and Egress	18
Effect of Development on Wider Catchment	20
4. FLOOD RISK MITIGATION	22
Sequential Arrangement	22
Development Levels.....	23
Safe Access and Egress	23
Development Drainage.....	23
5. CONCLUSIONS AND RECOMMENDATIONS	24

FIGURES

Figure 1.1: Site Location
Figure 1.2: Proposed layout
Figure 2.1: Flood Map for Planning
Figure 3.1: Modelled fluvial flood extents
Figure 3.2: Reservoir Flood Risk Map
Figure 3.3: Surface water flood map
Figure 3.4: Flood Evacuation Routes Including Modelled 1 in 100yr+22% Hazard Rating
Figure 3.5: Flood depths along northern access route
Figure 3.6: Flood depths along southern access route
Figure 4.1: Modelled 1 in 100yr +22%CC Flood Extent Overlaid on Masterplan

TABLES

Table 1-1: Site Summary
Table 2.1: Peak River Flow Allowance for the Tame, Anker and Mease Management Catchment
Table 2.2: Application of the Appropriate Climate Change Allowances
Table 2.3: Hazard to People
Table 3.1: Pre-Mitigation Sources of Flood Risk
Table 3.2: Modelled Flood Levels at the Site
Table 5.1: Summary of Flood Risk Assessment

APPENDICES

Appendix 1: Topographic Survey
Appendix 2: Hydraulic Modelling Study
Appendix 3: LLFA Liaison

1. INTRODUCTION

- 1.1 This Flood Risk Assessment (FRA) has been prepared in accordance with the requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance. The FRA has been produced on behalf of A R Cartwright (Construction) Ltd in respect of a planning application for residential development off Chapel Lane, Witherley.
- 1.2 This FRA is intended to support an outline planning application and as such the level of detail included is commensurate and subject to the nature of the proposals. Summary information is included as **Table 1-1**.

Table 1-1: Site Summary

Site Name	Land off Chapel Lane
Location	Witherley
NGR (approx.)	SP329975
Application Site Area (ha)	0.50 ha
Development Type	Residential
Flood Zone Classification	Flood Zones 1, 2 and 3
NPPF Vulnerability	More Vulnerable
Environment Agency Office	Staffordshire, Warwickshire and West Midlands
Lead Local Flood Authority	Leicestershire County Council
Local Planning Authority	Hinckley and Bosworth Borough Council

Sources of Data

- i. Topographical Survey by Tower Surveys Ltd (2013)
- ii. OS Explorer Series mapping
- iii. Environment Agency consultation
- iv. Leicestershire County Council Consultation
- v. Environment Agency Flood Maps
- vi. Hinckley and Bosworth Borough Strategic Flood Risk Assessment
- vii. Leicestershire County Council Preliminary Flood Risk Assessment
- viii. Hydraulic modelling of the Witherley Brook undertaken by BWB Consulting [ref ARC100-BWB-EWE-XX-RP-EN-0001]

- ix. Web Based Soil Mapping
- x. Severn Trent Sewer Records
- xi. British Geological Survey Drift & Geology Maps
- xii. Environment Agency Initial Assessment Report (IAP) - 2019

Existing Site

- 1.3 The site is located to the south of Chapel Lane in Witherley, a parish on the eastern edge of Atherstone. The site is bound and accessed by Chapel Lane to the north, with existing residential development to the west and greenfield land to the east. The Witherley Brook tributary lies to the south. The site's location is illustrated within **Figure 1.1**.

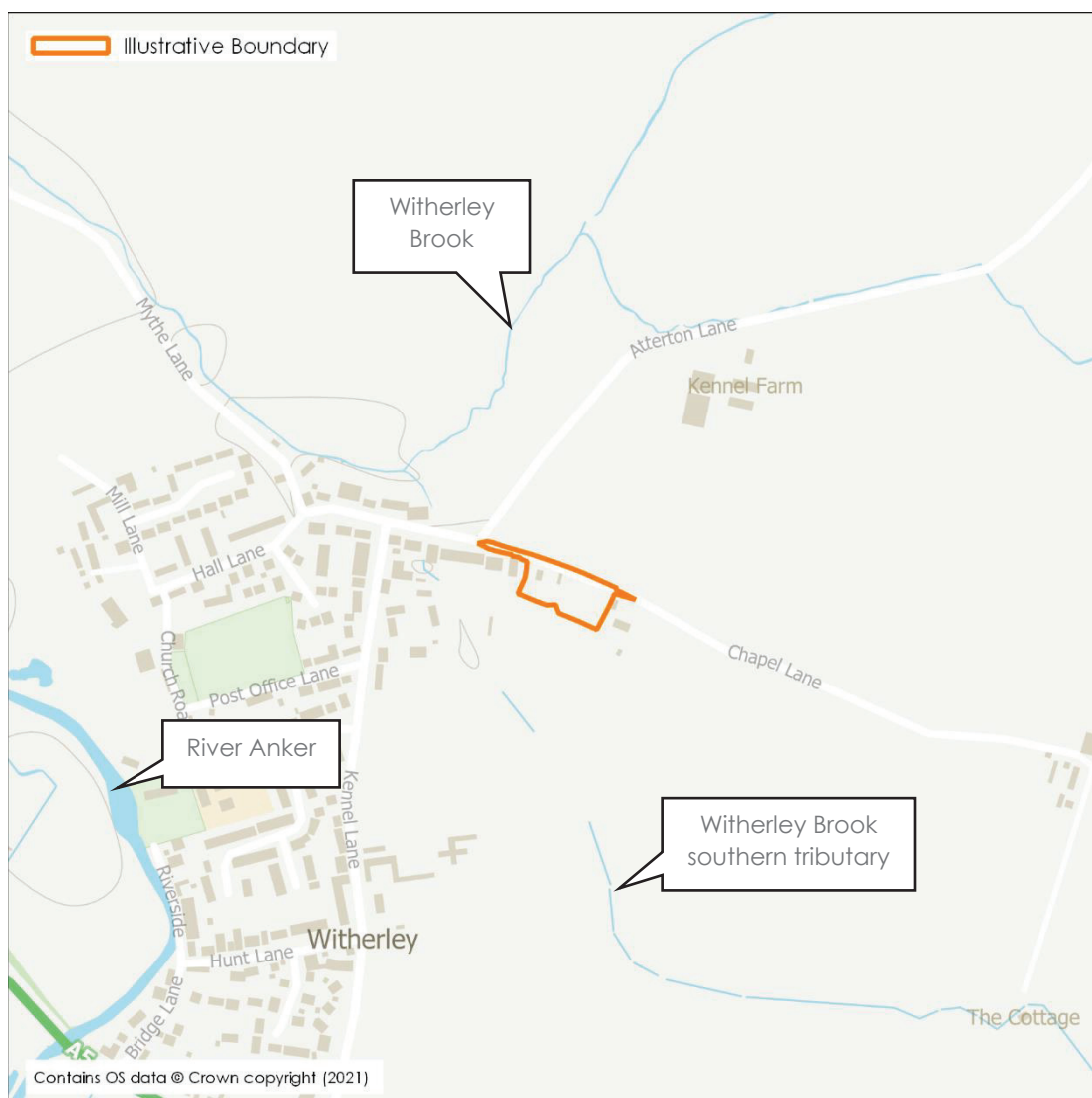


Figure 1.1: Site Location

- 1.4 A topographic survey has been provided which shows that levels across the site drain from north to south towards the watercourse. The lowest levels at the site are located in the south west corner. Levels are shown to fall by approximately 0.4m progressing south

through the site, with the north at 71.4mAOD and the south at 71mAOD. The topographic survey can be seen in **Appendix 1**.

- 1.5 The site currently comprises a mixture of hardstanding and disused outbuildings to the north and greenfield land.
- 1.6 With reference to the British Geological Survey (BGS) Geology of Britain Viewer, the site is underlain by Gunthorpe Member (Mudstone), with Lacustrine superficial deposits (Clay, Silt and Sand) also identified. The Soilscales website supports this, referencing the soils as being loamy and clayey with impeded drainage.

Proposed Development

- 1.7 The proposed development is residential in nature and consists of five separate plots with associated parking, landscaping and gardens. The site will be accessed directly off Chapel Lane. The proposed layout is displayed in **Figure 1.2**.



Figure 1.2: Proposed layout

2. FLOOD RISK PLANNING POLICY

National Planning Policy Framework

- 2.1 The NPPF¹ sets out the Government's national policies on different aspects of land use planning in England in relation to flood risk. Planning Practice Guidance is also available online².
- 2.2 The Planning Practice Guidance sets out the vulnerability to flooding of different land uses. It encourages development to be located in areas of lower flood risk where possible and stresses the importance of preventing increases in flood risk off site to the wider catchment area.
- 2.3 The Planning Practice Guidance also states that alternative sources of flooding, other than fluvial (river flooding), should be considered when preparing a Flood Risk Assessment.
- 2.4 The Planning Practice Guidance includes a series of tables that define Flood Zones (Table 1), the flood risk vulnerability classification of development land uses (Table 2) and 'compatibility' of development within the defined Flood Zones (Table 3).
- 2.5 This Flood Risk Assessment is written in accordance with the NPPF and the Planning Practice Guidance.

Flood Map for Planning

- 2.6 With particular reference to planning and development, the Flood Map for Planning produced by the Environment Agency identifies Flood Zones in accordance with Table 1 of the Planning Practice Guidance.
- 2.7 Flood Zone 1 (Low Probability) is defined as land having less than a 1 in 1000 annual probability of river or sea flooding (<0.1% Annual Exceedance Probability).
- 2.8 Flood Zone 2 (Medium Probability) is defined as land having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1% AEP); or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1% AEP).
- 2.9 Flood Zone 3a (High Probability) is defined as land having a 1 in 100 or greater annual probability of river flooding (>1% AEP); or land having a 1 in 200 or greater annual probability of flooding from the sea (>0.5% AEP). This is represented by "Flood Zone 3" on the Flood Map for Planning.
- 2.10 Flood Zone 3b (The Functional Floodplain) is defined as land where water has to flow or be stored in times of flood. This is not identified or separately distinguished from Zone 3a on the Flood Map for Planning.

¹ Revised National Planning Policy Framework, Ministry of Housing, Communities & Local Government, August 2021.

² Planning Practice Guidance: <https://www.gov.uk/government/collections/planning-practice-guidance>

- 2.11 The site is shown to be located predominantly within Flood Zone 1, with the far north west of the site being partially located in Flood Zones 2 and 3, as shown in **Figure 2.1**. The area where development is proposed to be sited is shown to be located entirely within Flood Zone 1, with Flood Zones restricted to the site access.



Figure 2.1: Flood Map for Planning

- 2.12 However, the Flood Map for Planning is limited to watercourses with a catchment above 3km², therefore, the southern tributary of the Witherley Brook is not represented. However, detailed hydraulic modelling has been carried out to support this FRA. The findings of this exercise are discussed in detail within **Section 3.0**.
- 2.13 The Witherley Brook is categorised as an EA main river downstream of Atterton Lane.

The Design Flood

- 2.14 The Planning Practice Guidance identifies that new developments should be designed to provide adequate flood risk management, mitigation, and resilience against the 'design flood' for their lifetime.

- 2.15 This is a flood event of a given annual flood probability, which is generally taken as fluvial (river) flooding likely to occur with a 1% annual probability (a 1 in 100 chance each year), or tidal flooding with a 0.5% annual probability (1 in 200 chance each year), against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed.

Climate Change

- 2.16 Predicted future change in peak river flows caused by climate change are provided by the Environment Agency within their online guidance³, with a range of projections applied to 'Management Catchments'. These are sub-catchments of regionalised 'River Basin Districts'.
- 2.17 The Witherley Brook falls within the 'Tame, Anker and Mease' Management Catchment which is located within the 'Humber' River Basin District. **Table 2.1** identifies the relevant peak river flow allowances.

Table 2.1: Peak River Flow Allowance for the Tame, Anker and Mease Management Catchment

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

- 2.18 When determining the appropriate allowance for use in a Flood Risk Assessment the Flood Zone classification, flood risk vulnerability and the anticipated lifespan of the development should be considered. **Table 2.2** provides a matrix summarising the Environment Agency's guidance on determining the appropriate allowances.

Table 2.2: Application of the Appropriate Climate Change Allowances

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

³ Environment Agency, Flood risk assessments: climate change allowances: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1>. Accessed August 2021.

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

- 2.19 The site is located within Flood Zones 1, 2 and 3. The proposed development is classified as 'More Vulnerable', and it has an anticipated lifespan of 100 years. Therefore, the Central allowance for the '2080s' epoch will be considered.
- 2.20 Therefore, to ensure the development is designed adequately for its lifetime, an allowance of +22% will be applied to the design flood to identify minimum development levels.
- 2.21 The upper end climate change allowances are reserved for Nationally Significant Infrastructure Projects (NSIPs), new settlements and urban extensions, where an additional 'sensitivity test' is required. Therefore, this does not need to be considered for this development.

Strategic Flood Risk Assessment

- 2.22 A Strategic Flood Risk Assessment (SFRA) is a study carried out by one or more local planning authorities to assess the risk to an area from flooding from all sources, now and in the future.
- 2.23 The Hinkley and Bosworth Level 1 SFRA⁴ has been reviewed in the production of this FRA. The SFRA provides information specific to the region in the form of fluvial, surface water and groundwater flood risk mapping, as well as records of historical flooding. Information from the Level 1 SFRA will be referenced within **Section 3.0** where applicable.
- 2.24 The site is also covered by the Leicestershire and Leicester City SFRA⁵, which was completed in 2017. This was commissioned to provide up to date guidance on flood risk and planning policy, as well as assess the future risk of flooding.

Preliminary Flood Risk Assessment

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

⁴ Hinkley and Bosworth Level 1 Strategic Flood Risk Assessment (JBA, 2019)

⁵ Leicestershire and Leicester City SFRA. JBA Consulting. October 2017.

- 2.26 The Leicestershire County Council PFRA⁶ considers flooding from surface water runoff, groundwater, ordinary watercourses and canals. It also references the historical river flooding which occurred in Leicestershire in 1998, 2002 and 2006. However, no historical instances of flooding at the site are referenced. Information from the PFRA will be referenced within this report where applicable.

Local Flood Risk Management Strategy

- 2.27 A Local Flood Risk Management Strategy (LFRMS) is prepared by a Lead Local Flood Authority to help understand and manage flood risk at a local level.
- 2.28 The LFRMS aims to ensure that the knowledge of local flood risk issues is communicated effectively so that they can be better managed. The LFRMS also aims to promote sustainable development and environmental protection.
- 2.29 The Leicestershire LFRMS⁷ has been reviewed and will be referenced within this report where applicable.

Other Relevant Policy and Guidance

Flood Risk to People and New Developments

- 2.30 The Flood Risk to People (FD2321/TR1)⁸ document was prepared as a research project considering flood hazard and factors that affect it.
- 2.31 Flood Risk Assessment Guidance for New Development (FD2320/TR2)⁹ provides a framework and guidance for assessing and managing flood risks for new developments and sets flood hazard thresholds.
- 2.32 Hazard ratings are derived using the following equation in line with the above:

$$\text{Hazard Rating} = D * (V+0.5) + DF$$

Where:
D = depth
V = velocity
DF = debris factor

- 2.33 A supplementary note¹⁰ provides clarification of the hazard rating thresholds which should be used for development planning and control use. **Table 2.3** identifies the thresholds of the flood hazard categories.

⁶ Leicestershire County Council Preliminary Flood Risk Assessment (Scott Wilson, 2011)

⁷ Leicestershire County Council Local Flood Risk Management Strategy (Leicestershire County Council, 2015)

⁸ Flood Risk to People Methodology (FD2321/TR1), Defra/Environment Agency, 2006

⁹ Flood Risk Assessment Guidance for New Development (FD2320/TR2), Defra/Environment Agency, 2005

¹⁰ Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose – Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1. (http://randd.defra.gov.uk/Document.aspx?Document=FD2321_7400_PR.pdf)

Table 2.3: Hazard to People¹¹

Threshold for Flood Hazard Rating	Degree of Flood Hazard	Description
< 0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 - 1.25	Moderate	Danger for some (i.e.: children, the elderly and the infirm) "Danger: Flood Zone with deep or fast flowing water"
1.25 - 2.0	Significant	Danger for most (includes the general public) "Danger: Flood Zone with deep fast flowing water"
> 2.0	Extreme	Danger for all (includes the emergency services) "Extreme Danger: Flood Zone with deep fast flowing water"

Improving the Flood Performance of New Buildings; Flood Resilient Construction

- 2.34 The Flood Resilient Construction¹² document is the outcome of a joint research project between Communities and Local Government and the Environment Agency. A Research and Development Technical Report¹³ is also available.
- 2.35 The document provides guidance on flood resilient design and construction and possible techniques and building materials. These documents are referred to in this Flood Risk Assessment and have been considered when recommending mitigation and resilience measures.

¹¹ 2008, DEFRA, Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purposes.

¹² Improving the Flood Performance of New Buildings; Flood Resilient Construction, CLG, May 2007

¹³ Flood Resistance and Resilience Solutions; an R&D Scoping Study, Defra/Environment Agency, 2007

3. POTENTIAL SOURCES OF FLOOD RISK

- 3.1 Flooding can occur from a variety of sources, or combination of sources, which may be natural or artificial. **Table 3.1** below identifies the potential sources of flood risk to the site in its current condition, and the impacts which the development could have in the wider catchment, prior to mitigation. These are discussed in greater detail in the forthcoming section. Reports of historical flooding have been summarised and combined at the end of the section.
- 3.2 The mitigation measures proposed to address flood risk issues and ensure the development is appropriate for its location are discussed within **Section 4.0**.

Table 3.1: Pre-Mitigation Sources of Flood Risk

Flood Source	Potential Risk				Description
	High	Medium	Low	None	
Fluvial	X				The site is located predominantly in Flood Zone 1 and partially in Flood Zones 2 and 3.
			X		A tributary of the Witherley Brook lies south of the application site. Hydraulic modelling has shown that the application site sits outside of the flood extents.
Coastal				X	The site is not in an area at risk of coastal flooding.
Canals				X	The nearest canal is located 1.6km south west of the site.
Groundwater		X			The site is shown to fall within an area predicted to be at a medium susceptibility to groundwater flooding.
Reservoirs and waterbodies				X	The site is shown to fall outside of the area at risk of reservoir failure.
Pluvial runoff			X		The application site largely sits in the very low category, with the low risk events affecting parts of the south.
Sewers			X		A 150mm sewer is located on Chapel Lane. Whilst this may have limited capacity, the exceedance would follow the roadway and convey west towards Atterton Lane.

Flood Source	Potential Risk				Description
	High	Medium	Low	None	
Effect of Development on Wider Catchment			X		The application site sits outside of the modelled flood extents.
	X				The development will increase the area of impermeable surfaces leading to a potential increase in runoff.

Fluvial Flood Risk

- 3.3 Flooding from watercourses occurs when flows exceed the capacity of the channel, or where a restrictive structure is encountered, which leads to water overtopping the banks into the floodplain. This process can be exacerbated when debris is mobilised by high flows and accumulates at structures.
- 3.4 The site lies to the north of the southern tributary of the Witherley Brook, which is not represented on the EA Flood Maps due to its catchment area being too small. Therefore, the Flood Zone designation referred to in **Section 2.0** is not fully representative and site-specific hydraulic modelling has been carried out.

Site Specific Hydraulic Modelling

- 3.5 Detailed hydraulic modelling was initially completed by BWB for the site in 2016, when the site was originally being submitted for planning. The model has since been updated in 2021 to account for the updates to the hydrological methods, hydraulic modelling software and climate change guidance. Please see **Appendix 2** for further details.
- 3.6 A comprehensive modelling assessment was completed, combining a number of Witherley Brook and River Anker events. Due to the difference in catchment area of the two watercourses (8.4km² vs 141km²), the coincidence of extreme flood events with the same flood return period is considered more unlikely. However, a conservative approach has been adopted with treats the “combined” event as the design event, with a 1 in 100yr+22% event modelled on both the Witherley Brook and the River Anker downstream.
- 3.7 The floodplain for the combined events across a variety of return periods is illustrated in **Figure 3.1** below. Flood levels can also be found in **Table 3.2**. The flood levels were taken from the floodplain and are uniform across the site.

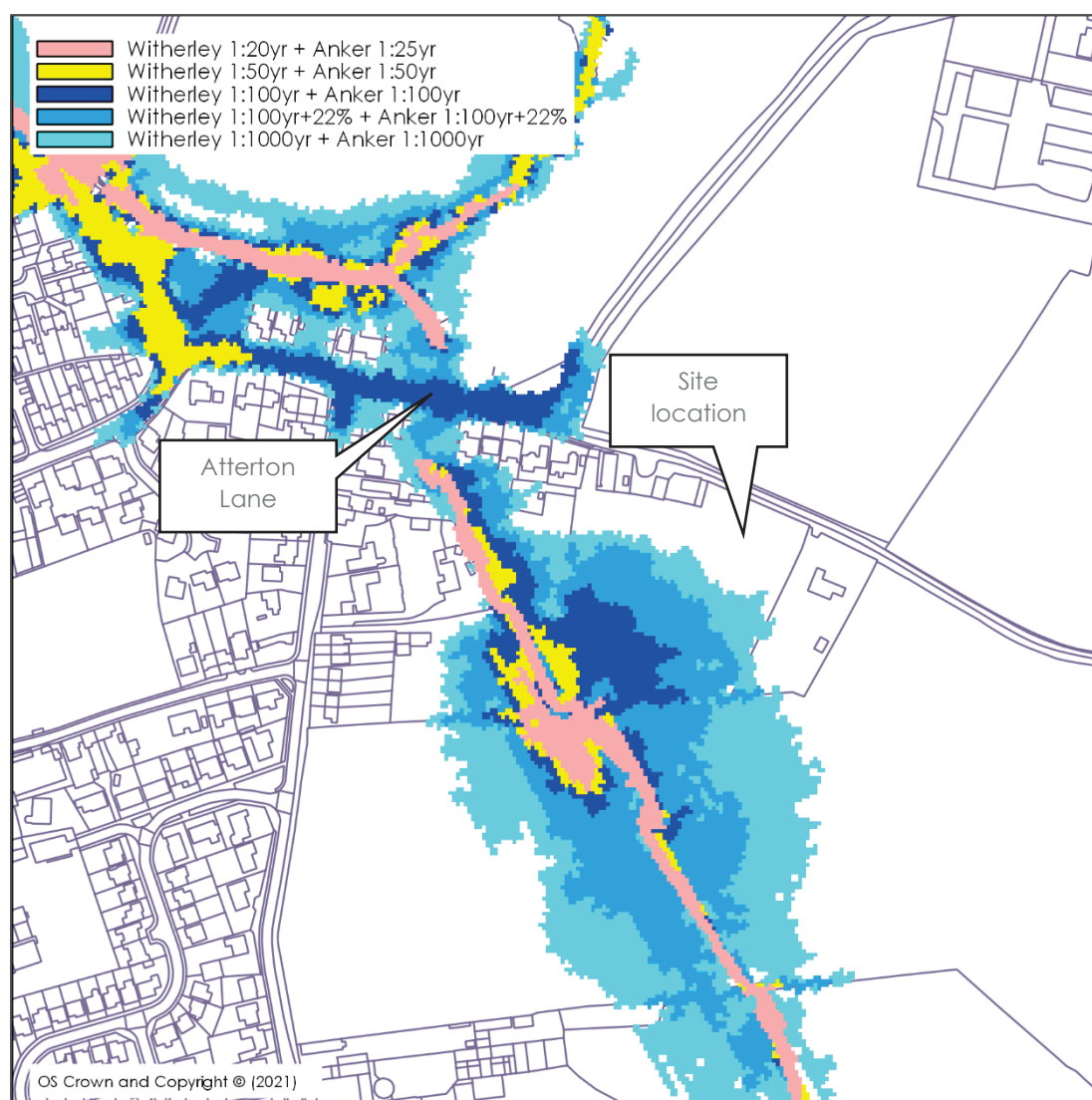


Figure 3.1: Modelled fluvial flood extents

Table 3.2: Modelled Flood Levels at the Site

Return Period	Flood Level (mAOD)
1:20yr	70.61
1:50yr	70.64
1:100yr	70.67
1:100yr+22% (design event)	70.80
1:1000yr	70.93

- 3.8 Flooding at the site is controlled by the capacity of the Atterton Lane culvert, which results in uniform flood levels upstream of the culvert when its capacity is exceeded (return period events above a 1:20yr event). The application site sits outside of all modelled flood extents up to and including the design event.

- 3.9 The outputs demonstrate that the River Anker modelled flood levels have a limited impact upstream of the Atterton Lane culvert and are more of an issue for the downstream village.
- 3.10 A complete blockage was also modelled on the Atterton Lane culvert to identify the impacts that this would have on the site. The model showed that a full blockage of the culvert would increase flood levels at the site by 0.16m during the design event.
- 3.11 Mitigation measures are recommended in **Section 4.0**.

Coastal/Tidal Flood Risk

- 3.12 Inundation of low-lying coastal areas by the sea may be caused by seasonal high tides, storm surges and storm driven wave action. Coastal flooding is most commonly a result of a combination of two or more of these mechanisms, which can result in the overtopping or breaching of sea defences. River systems may also be subject to tidal influences.
- 3.13 The closest coastline to the site is approximately 115km northeast. Therefore, the site is not located in an area affected by coastal flooding or the tide.

Flood Risk from Canals

- 3.14 The Canal and River Trust (CRT) generally maintains canal levels using reservoirs, feeders and boreholes and manages water levels by transferring it within the canal system.
- 3.15 Water in a canal is typically maintained at predetermined levels by control weirs. When rainfall or other water enters the canal, the water level rises and flows out over the weir. If the level continues rising it will reach the level of the storm weirs. The control weirs and storm weirs are normally designed to take the water that legally enters the canal under normal conditions. However, it is possible for unexpected water to enter the canal or for the weirs to become obstructed. In such instances the increased water levels could result in water overtopping the towpath and flowing onto the surrounding land.
- 3.16 Flooding can also occur where a canal is impounded above surrounding ground levels and the retaining structure fails.
- 3.17 The nearest canal is located approximately 1.6km southwest of the site, which is the Coventry Canal. This canal passes through Atherstone and is on the opposite side of the River Anker valley to the site. Therefore, the site is not considered to be at risk of canal flooding.

Groundwater Flood Risk

- 3.18 Groundwater flooding occurs when the water table rises above ground elevations. It is most likely to happen in low lying areas underlain by permeable geology. This may be regional scale chalk or sandstone aquifers, or localised deposits of sands and gravels underlain by less permeable strata such as that in a river valley.

- 3.19 The groundwater risk has been assessed by reviewing the SFRA⁴, BGS Geological Viewer, and Magic Map viewer developed by DEFRA.
- 3.20 The SFRA reports Areas Susceptible to Groundwater Flooding at a 1km² resolution across Hinckley and Bosworth Borough Council. The site is shown to be located within a tile whereby 50-75% of the area is considered to be susceptible to groundwater flooding.
- 3.21 The site is shown to be located outside of all EA designated Groundwater Source Protection Zones.
- 3.22 With reference to the British Geological Survey (BGS) Geology of Britain Viewer, the site is underlain by Gunthorpe Member (Mudstone). This is defined as a 'Secondary B' aquifer which are predominantly lower permeability layers. These may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.
- 3.23 The BGS also identify the presence of Lacustrine superficial deposits (Clay, Silt and Sand) at the site. These are defined as unproductive aquifers.
- 3.24 The availability of borehole data at the site was limited, with the nearest historical borehole log located north of Chapel Lane [ref: SP39NW10]. This reports groundwater being struck at 5m below ground level (bgl). However, due to the site being located in the floodplain of the Witherley Brook tributary, groundwater patterns are likely to differ.
- 3.25 Overall, the risk posed by groundwater is moderate and mitigation measures are discussed in **Section 4.0**.

Flood Risk from Reservoirs & Large Waterbodies

- 3.26 Flooding can occur from large waterbodies or reservoirs if they are impounded above the surrounding ground levels or are used to retain water in times of flood. Although unlikely, reservoirs and large waterbodies could overtop or breach leading to rapid inundation of the downstream floodplain.
- 3.27 To help identify this risk, reservoir failure flood risk mapping has been prepared, this shows the largest area that might be flooded if a reservoir were to fail and release the water it holds. The map displays a worst-case scenario and is only intended as a guide.
- 3.28 The site sits outside of the reservoir flood extent. Areas subject to reservoir flood risk near the site are limited the Witherley Brook downstream of the Atterton Lane culvert. This is illustrated in **Figure 3.2**.



Figure 3.2: Reservoir Flood Risk Map

Pluvial Flood Risk

- 3.29 Pluvial flooding can occur during prolonged or intense storm events when the infiltration potential of soils, or the capacity of drainage infrastructure is overwhelmed leading to the accumulation of surface water and the generation of overland flow routes.
- 3.30 Risk of flooding from surface water mapping has been prepared. This shows the potential flooding which could occur when rainwater does not drain away through the normal drainage systems or soak into the ground but lies on or flows over the ground instead. An extract from the mapping is included as **Figure 3.3**.

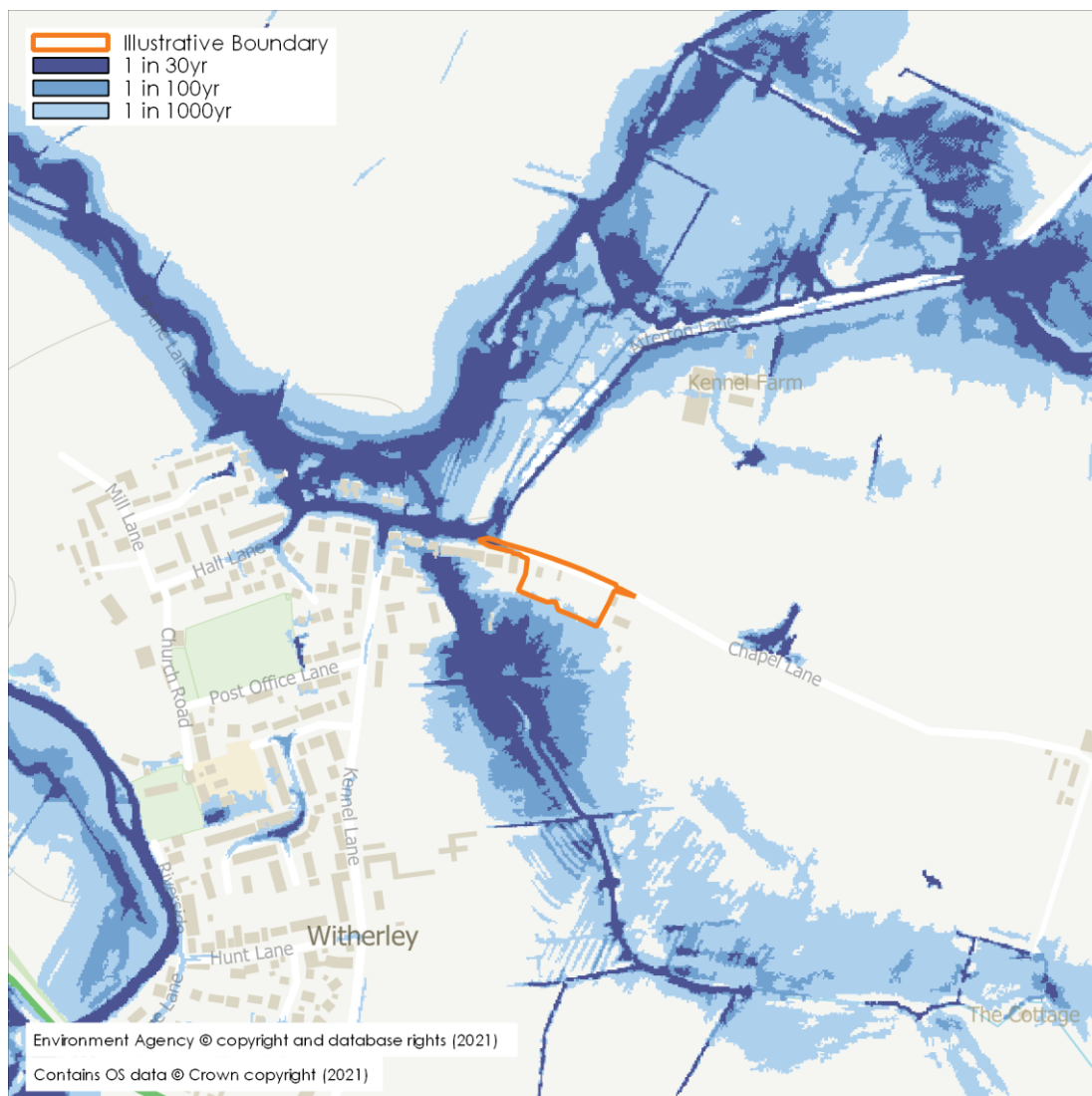


Figure 3.3: Surface water flood map

- 3.31 The pluvial flood mapping shows that the site is largely at very low risk, with low-risk areas along the southern boundary and isolated areas at high risk in the far west, along the access road. However, given the presence of the watercourse, the risk shown is thought to be fluvial in origin. The mapping therefore represents a worst-case scenario as it does not include the representation of hydraulic structures such as culverts.

Flood Risk from Sewers

- 3.32 Sewer flooding can occur when the capacity of the infrastructure is exceeded by excessive flows, or as a result of a reduction in capacity due to collapse or blockage, or if the downstream system becomes surcharged. This can lead to the sewers flooding onto the surrounding ground via manholes and gullies, which can generate overland flows.
- 3.33 The nearest sewer to the site is located to the north along Chapel Lane. This is a 150mm diameter combined public sewer. Whilst this may have limited capacity, any

exceedance would follow the topography and convey along Chapel Lane towards Atterton Lane.

- 3.34 Given the local topography and low density of public sewers around the site, the overall risk of sewer flooding to the development is low.

Historical Instances of Flooding in the Region

- 3.35 The SFRA⁴ for the Borough has been reviewed in light of historical instances of flooding, to further understand potential sources of risk to the site. The LLFA have also been contacted for instances of historical flooding, the full details of which can be viewed in **Appendix 3**. Additionally, the EA's Initial Assessment Report (IAP)¹⁴ defines the historical flooding problems in the surrounding area. The following historical events in the borough have been identified through a combination of these data sources:

- **December 1992** – Fluvial flooding from the River Anker
- **July 2007** – Flooding along Atterton, Chapel, Mythe and Kennel Lane
- **June and November 2012** - Flooding along Atterton, Chapel, Mythe and Kennel Lane
- **July 2013** – Surface water flooding to properties borough-wide
- **January 2014** – Borough-wide flooding to highways from surface water, fluvial flooding due to blocked culverts
- **February 2016** - Flooding along Atterton, Chapel, Mythe and Kennel Lanes
- **March 2016** – Borough-wide flooding to highways and properties from fluvial and surface water sources
- **June 2016** – Borough-wide flooding to highways from surface water
- **January 2018** – Borough-wide flooding from surface water and public sewers

- 3.36 Notably, historical flooding has not been reported on the developable area; however, there are previous instances of flooding along the access route to the site. The events listed above also provide context on the flooding problems present in the downstream village of Witherley.

Access and Egress

- 3.37 Given the flood history of highways in the local area, a detailed review of the modelled results along the site access route has been carried out to demonstrate that routes will be safely passable by the emergency services during key modelled events. The access routes and the Flood Hazard rating for the 1 in 100yr event are displayed below in **Figure 3.4**.

¹⁴ Initial Assessment Report, Witherley, February 2019, Environment Agency, Final version.

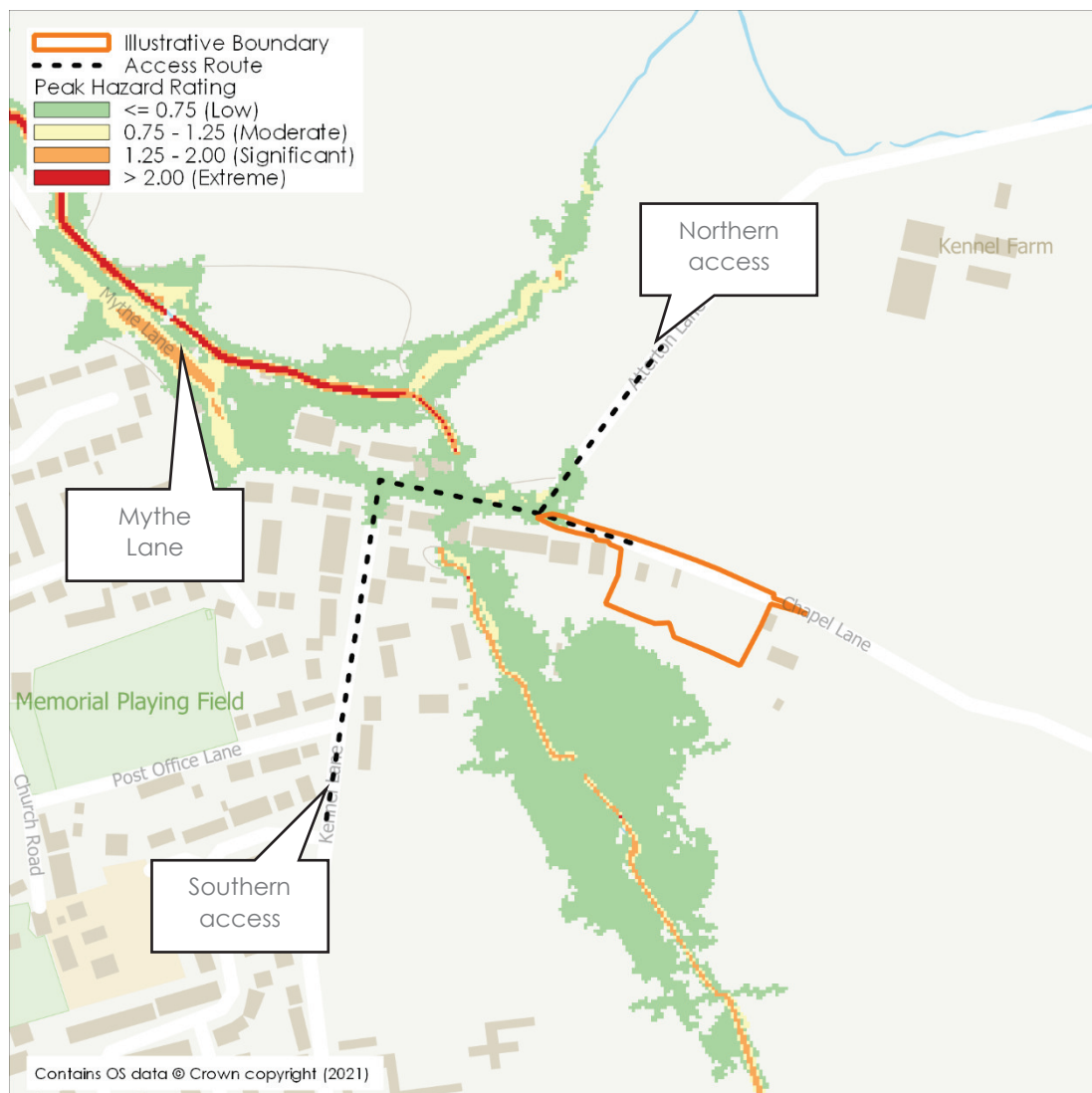


Figure 3.4: Flood Evacuation Routes Including Modelled 1 in 100yr+22% Hazard Rating

- 3.38 Flooding along Chapel Lane adjacent to the site and to the east (upstream) is limited due to the position of the watercourse lying further south at a greater distance from the highway. Towards the junction with Atterton Lane and Kennel Lane, flooding increases and becomes significant along Mythe Lane, in line with historical flooding reports.
- 3.39 The access route from the site becomes inundated for a stretch of approximately 100m during the 1 in 100yr event. The hazard rating however is contained within the “low” category, meaning that it will be passable. Depths during this event peak at 0.35m and velocities are low at <0.15m/s.
- 3.40 The flood depths along each access route for a number of events are included in **Figure 3.5** and **Figure 3.6**. Whilst these do not explicitly model surface water, they are thought to be the best representation of flooding at the junctions, as a significant portion of the flooding shown on the surface water flood maps is clearly fluvial in origin, from the Witherley Brook. Further south on Kennel Lane, the surface water risk is shown to be very low by online mapping.

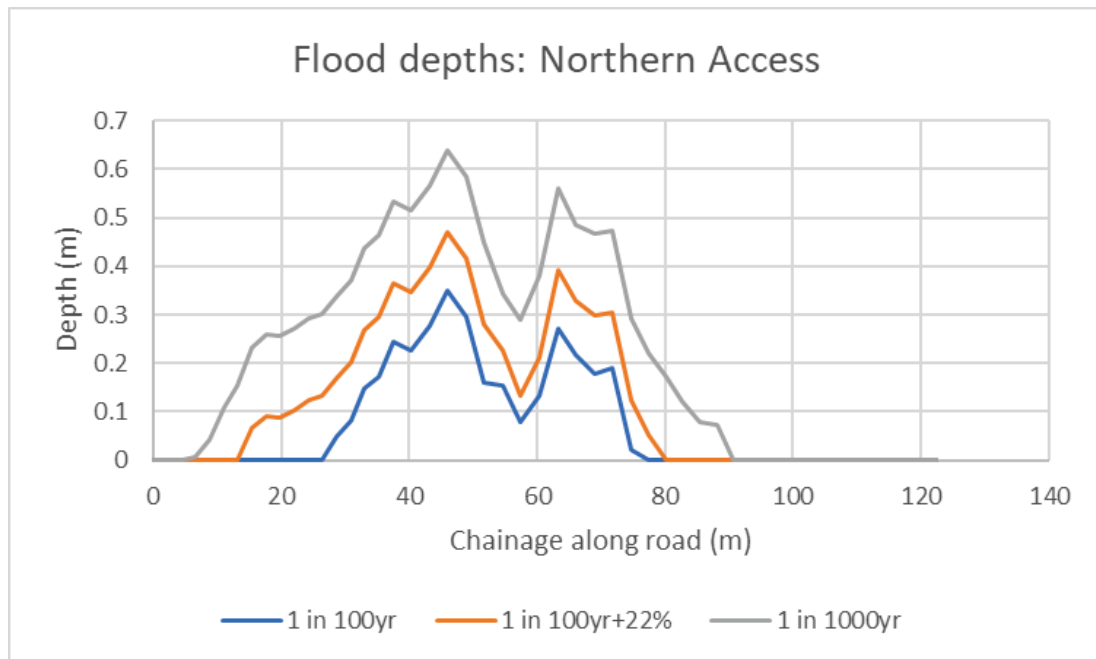


Figure 3.5: Flood depths along northern access route

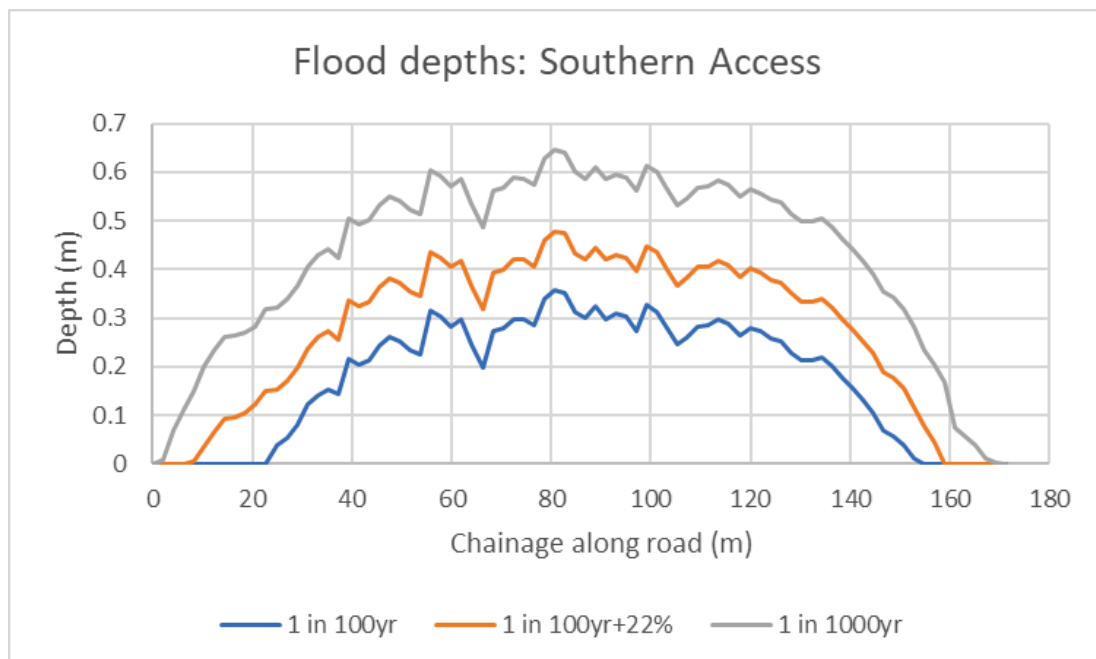


Figure 3.6: Flood depths along southern access route

Effect of Development on Wider Catchment

Displacement of Floodplain

- 3.41 The application site has been sequentially located so that it falls outside of the Witherley Brook tributary floodplain. Therefore, the fluvial risk of flooding to the local area will not be affected by the development.

Drainage Considerations

- 3.42 A separate sustainable drainage statement will be prepared and submitted to planning by a third party. This should ensure that the flood risk is not made worse by the development and that there is sufficient capacity within the public sewer system to receive flows from the development where required.

4. FLOOD RISK MITIGATION

- 4.1 **Section 3.0** has identified the sources of flooding which could potentially pose a risk to the site and the proposed development. This section of the FRA sets out the mitigation measures which are to be incorporated within the proposed development to address and reduce the risk of flooding to within acceptable levels.

Sequential Arrangement

- 4.2 The development has been arranged so that it is located entirely outside of the floodplain for the design event (1 in 100yr+22%), as well as the 1 in 1000yr floodplain. This confirms that the development will not impede flow routes or affect existing floodplain storage, thus having no effect on flood risk to the downstream village. This is demonstrated in **Figure 4.1**.

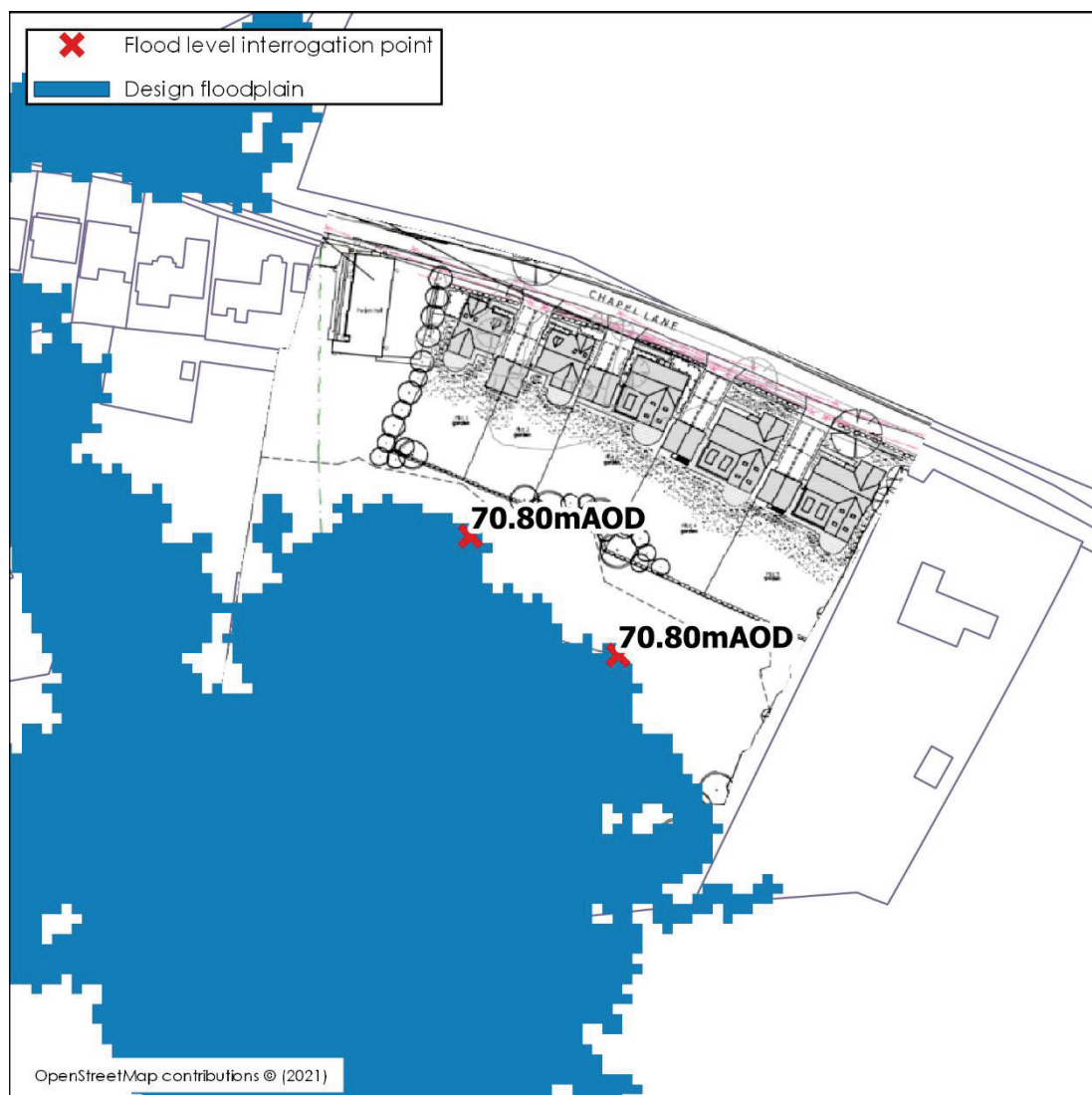


Figure 4.1: Modelled 1 in 100yr +22%CC Flood Extent Overlaid on Masterplan

Development Levels

- 4.3 In accordance with the Hinckley and Bosworth Borough Council SFRA, finished floor levels (FFL) should be set a minimum of 600mm above the 1 in 100 year plus climate change flood level (70.80mAOD). Accordingly, a minimum FFL of 71.40mAOD is required for all plots. A review of the topographic survey would mean that FFLs would be approximately 150mm above surrounding ground levels. This clearance should be maintained as a minimum to remove the residual risk of internal flooding to properties by either overland flow routes within the development or groundwater.
- 4.4 The residual risk to the development is also considered to be low, as this FFL would provide 440mm of freeboard against a blockage scenario during the design event, and 460mm of freeboard during an extreme 1 in 1000yr event.

Safe Access and Egress

- 4.5 **Section 3.0** has demonstrated that safe access to the site is possible during the 1 in 100yr +22%CC event via the south and north, with the southern route being at lowest risk (Kennel Lane).
- 4.6 As the plots will be two story, safe refuge will be available on upper floors in the case of a flood event on site.
- 4.7 Flood warnings downstream of the site are monitored by the Environment Agency; however, it is recommended that residents are aware of the various sources of flood warning information and services available, including, but not limited to the following:
- Met office weather forecasts and warnings
 - Environment Agency 24-hour Floodline
 - Environment Agency River monitoring stations (River Anker)

Development Drainage

- 4.8 A separate drainage strategy is being submitted by a third party to address the sustainable management of surface water and a strategy for foul water. It is recommended that the local sewerage undertaker is contacted to confirm capacity requirements.

5. CONCLUSIONS AND RECOMMENDATIONS

- 5.1 This FRA has been prepared in accordance with requirements set out in the NPPF and the associated Planning Practice Guidance. The FRA has been produced on behalf of A R Cartwright (Construction) Ltd in respect of a planning application for the residential development of a site off Chapel Lane, Witherley.
- 5.2 This FRA is intended to support a planning application and as such the level of detail included is commensurate and subject to the nature of the proposals.
- 5.3 This report demonstrates that the proposed development is at an acceptable level of risk, subject to the recommended flood mitigation strategies being implemented. The identified risks and mitigation measures are summarised within **Table 5.1**:

Table 5.1: Summary of Flood Risk Assessment

Flood Source	Risk & Proposed Mitigation Measures
Fluvial	The development remains flood free for all events up to and including the 1 in 100yr+22% climate change event, due to sequential placement ensuring that the development is not located in the floodplain. A minimum FFL of 71.40mAOD will provide 600mm freeboard above the design flood level and 440mm of freeboard above the design event with a complete blockage of the Atterton Lane culvert.
Coastal/Tidal	The site does not fall within a coastal flood risk zone.
Canals	The site is not at risk of canal flooding
Groundwater	The site is considered to be at moderate risk which has been mitigated by a sequential development layout and the raising of FFLs by a minimum of 150mm above surrounding ground.
Reservoirs and waterbodies	The site falls outside of an area at risk of reservoir flooding.
Pluvial runoff	The application site and proposed development has been strategically located so that the risk of pluvial flooding is low or very low (outside of a 1 in 1000yr event). The raising of floor levels will also mitigate against the exceedance of the surface water drainage system in an extreme event.
Sewers	The risk is considered low due to the surrounding topography and low density of public sewers in the area immediate to the site.
Impact of the Development	The development has been located so as to not encroach or displace any floodplain during all events up to an including the 1 in 100yr +22%CC event. A separate drainage strategy is being progressed by a third party for submission to planning to address the sustainable management of surface water and a foul strategy for the development.
This summary should be read in conjunction with BWB's full report. It reflects an assessment of the Site based on information received by BWB at the time of production.	

- 5.4 In compliance with the requirements of NPPF, and subject to the mitigation measures proposed, the development could proceed without being subject to significant flood risk. Moreover, the development will not increase flood risk to the wider catchment area subject to suitable management of surface water runoff discharging from the site.

APPENDICES

Appendix 1: Topographic Survey

Appendix 2: Hydraulic Modelling Study

ENVIRONMENT

A R Cartwright (Construction) LTD
Chapel Lane
Witherley
Witherley Brook Hydraulic Modelling

October 2021

Document Number:	ARC100-BWB-EWE-XX-RP-EN-0001
BWB Reference:	BMW-2465-TN1

Revision	Date of Issue	Status	Author:	Checked:	Approved:
P06	12/10/2021	S2	Alex Petrakis BSc. (Hons)	Robin Green BSc. (Hons)	Matthew Day BA (Hons) MSc FRGS MCIWEM C.WEM C.Sci C.Env

Notice

All comments and proposals contained in this report, including any conclusions, are based on information available to BWB Consulting during investigations. The conclusions drawn by BWB Consulting could therefore differ if the information is found to be inaccurate or misleading. BWB Consulting accepts no liability should this be the case, nor if additional information exists or becomes available with respect to this scheme.

Except as otherwise requested by the client, BWB Consulting is not obliged to and disclaims any obligation to update the report for events taking place after: -

- (i) The date on which this assessment was undertaken, and
- (ii) The date on which the final report is delivered

BWB Consulting makes no representation whatsoever concerning the legal significance of its findings or the legal matters referred to in the following report.

All Environment Agency mapping data used under special license. Data is current as of October 2021 and is subject to change.

The information presented, and conclusions drawn, are based on statistical data and are for guidance purposes only. The study provides no guarantee against flooding of the study site or elsewhere, nor of the absolute accuracy of water levels, flow rates and associated probabilities.

This document has been prepared for the sole use of the Client in accordance with the terms of the appointment under which it was produced. BWB Consulting Limited accepts no responsibility for any use of or reliance on the contents of this document by any third party. No part of this document shall be copied or reproduced in any form without the prior written permission of BWB

1. INTRODUCTION

- 1.1 BWB Consulting Ltd has been commissioned to undertake an update to the Witherley Brook hydraulic through Witherley, Leicestershire. The location of the study area is shown in **Figure 1-1**.

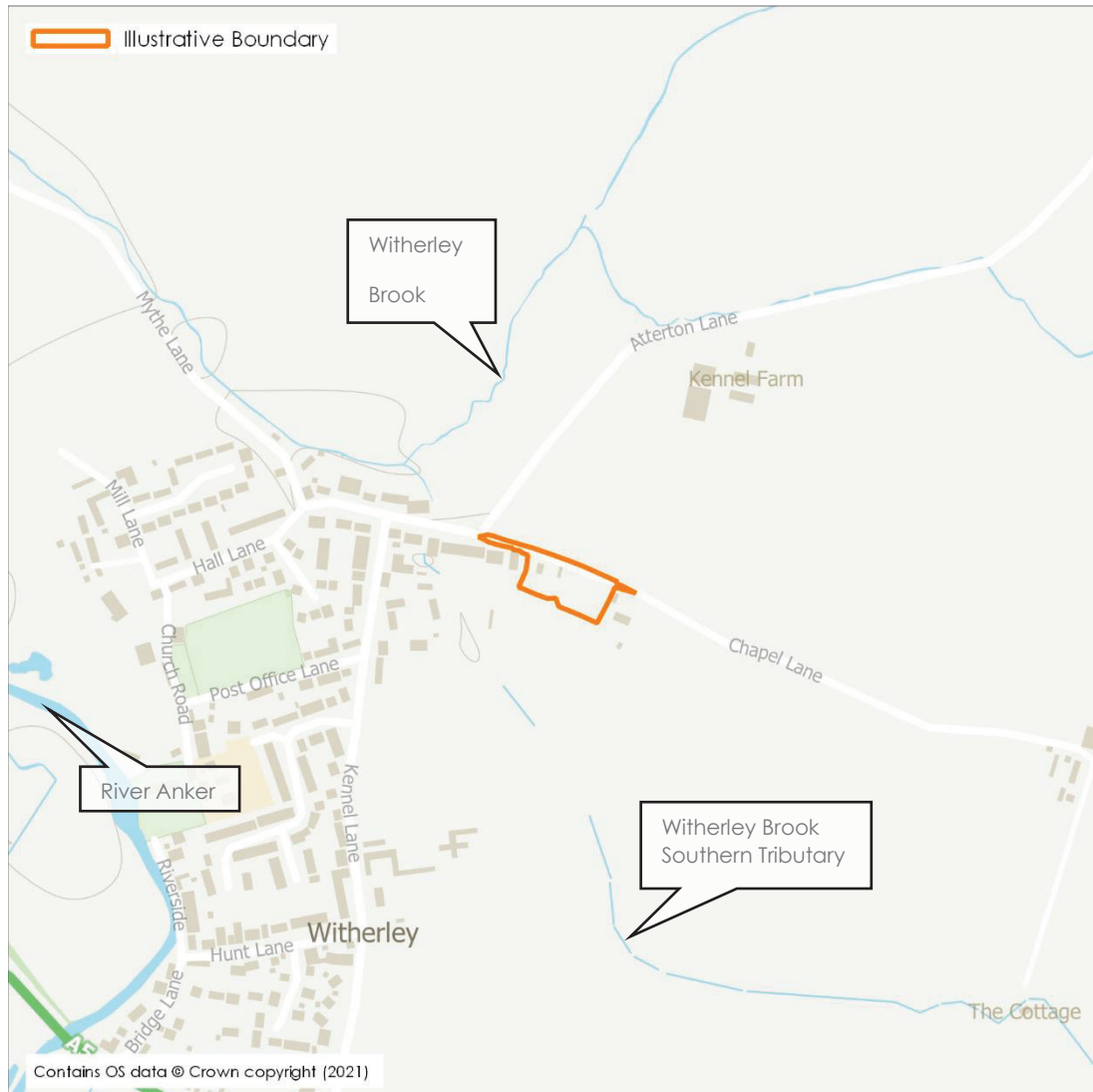


Figure 1-1: Site location

- 1.2 The Witherley Brook is comprised of two main branches at Witherley. The first drains an area located to the north and east of Witherley. This flows in a south-westerly direction towards Witherley, primarily through farmland.
- 1.3 A tributary or second branch of the Witherley Brook is located to the east/south-east of Witherley. This flows in a north-westerly direction through farmland. The channel passes through a series of residential gardens, before being culverted under Atterton Lane. The culvert outfalls on the northern side of Atterton Lane and joins the main channel of the Witherley Brook. The Witherley Brook in turn connects into the River Anker 800m to the north-west.

- 1.4 A previous model for the site was submitted to the EA by BWB Consulting during 2016 and approved. This hydraulic model was used to help inform a proposed site layout for planning submission, however, the time lapsed since the original model build has led to this model report being revised for potential future submissions.
- 1.5 This update (as of August 2021) includes the latest Light Detecting and Ranging (LiDAR) data, new peak flow estimates and the latest version of hydraulic modelling software to improve confidence in predicted flood levels. Whilst much of the model remains unchanged since the approval by the EA, the full model build details are included in this report for completeness.

Previous Studies & Available Data

- 1.6 The Environment Agency (EA) Flood Maps for Planning are illustrated within **Figure 1-2**. It is clear that the southern tributary channel is too small to have been included within the national Flood Zone coverage.
- 1.7 It is understood that the Witherley Brook downstream of Atterton Lane is also not fully represented, despite being classified as 'Main River' at this point, and that the illustrated Flood Zones are primarily associated with the River Anker.



Figure 1-2: EA Flood Maps

- 1.8 The EA has confirmed that the Witherley Brook has not been hydraulically modelled. Therefore, the hydraulic model developed by BWB Consulting is considered to remain the best available data.
- 1.9 The EA have provided a copy of the River Anker hydraulic model which was utilised within this exercise to inform the downstream boundary conditions.
- 1.10 EA surface water flood risk maps identify the potential areas at risk of flooding if rainwater does not enter the drainage system or infiltrate into the ground. While not strictly a fluvial source, this mapping can provide an indication of the potential flood risk associated with minor watercourses excluded from the Flood Zone maps.
- 1.11 An extract of the Surface Water Flood Risk maps is illustrated within **Figure 1-3**. This shows that there could be a relatively expansive floodplain associated with the Witherley Brook and its tributaries. It should be noted that this strategic level mapping is unlikely to include the culvert under Atterton Lane, therefore the upstream mapped extents could be overestimated.

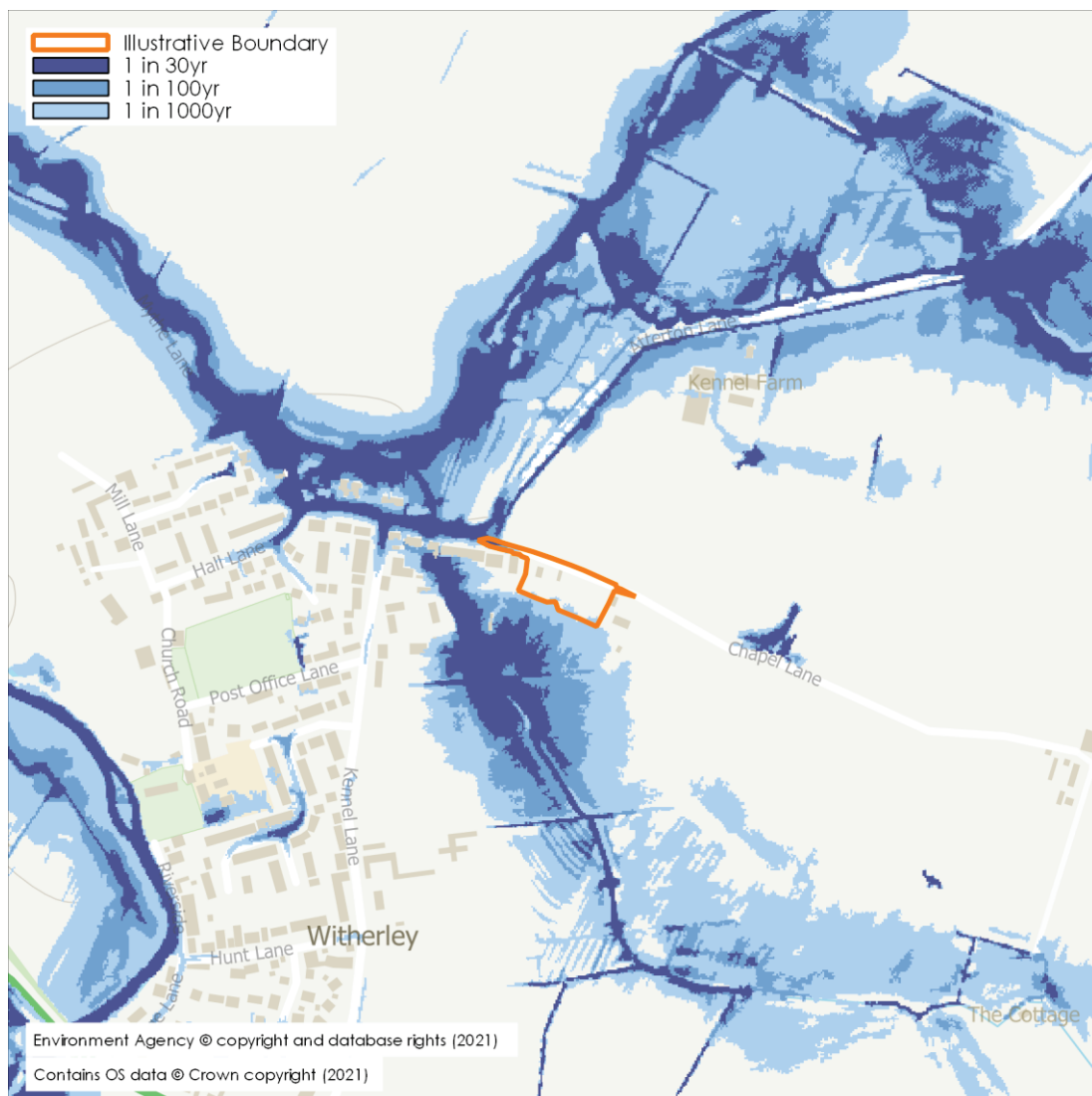


Figure 1-3: Surface Water Flood Map

Environment Agency Initial Assessment Report

- 1.12 An Initial Assessment Report (IAR) was completed by the EA during February 2019¹. The purpose of this was to undertake a review of the flooding history in Witherley and determine whether a Strategic Outline Case (SOC) was required based on the cost/benefit ratio of three shortlisted options. Despite the report referencing flooding in Witherley during 2007, 2012, 2014 and 2016, all three shortlisted options resulted in negative cost/benefit ratios. Therefore, the IAR did not progress to the SOC stage.

Other Sources of Data

- 1.13 The following additional datasets were used within the hydraulic modelling exercise:
- EA 2m LiDAR Composite Digital Terrain Model (DTM), downloaded in 2021

¹ Initial Assessment Report, Witherley, February 2019, Environment Agency, Final Version

- Flood Estimation Record completed by BWB in 2021 (ref: ARC100-BWB-ZZ-XX-RP-YE-0003_FER) – **Appendix 1**
- A watercourse survey of the Witherley Brook, undertaken in December 2015 – **Appendix 2**
- Ordnance Survey 1:1,250 scale mapping
- Photographs from a site visit undertaken in September 2015 by BWB Consulting
- Consultation with Highways England Drainage Engineers
- 2016 BWB Witherley Brook hydraulic model

Aims & Objectives

1.14 The primary aim of this exercise was to update the 2016 hydraulic model to re-establish a good hydrological and hydraulic representation of the fluvial flooding regime from the Witherley Brook within the study area.

1.15 To achieve this aim, the following objectives were identified:

- Update the hydraulic model geometry with the latest LiDAR data from the Environment Agency.
- Undertake a new hydrological assessment of the Witherley Brook catchment to estimate peak flood flows and generate flood hydrograph profiles.
- Simulate fluvial flood events within the combined 1D-2D model to establish a set of baseline conditions
- Simulate sensitivity tests and residual risks within the model, which would include roughness coefficients, blockage scenarios and climate change.

2. HYDROLOGICAL ASSESSMENT

Summary

- 2.1 A separate Flood Estimation Record has been completed, which is available as **Appendix 1**. This version of the report has been revised to include an updated hydrological assessment, completed in August 2021. This is due to the initial hydraulic modelling exercise being completed in 2016, and software and peak flows database having been updated since this date. A summary of the peak flows used in the modelling and the schematization of inflows are presented in **Table 2.1** and **Figure 2-1**.

Table 2.1 Peak Flows

Inflow area	1 in 10yr (m3/s)	1 in 20yr (m3/s)	1 in 50yr (m3/s)	1 in 75yr (m3/s)	1 in 100yr (m3/s)	1 in 1000yr (m3/s)
Northeast catchment	2.45	2.93	3.69	4.07	4.37	7.57
Southeast catchment	0.37	0.45	0.56	0.62	0.67	1.17
Lateral catchment	0.15	0.18	0.23	0.26	0.28	0.49

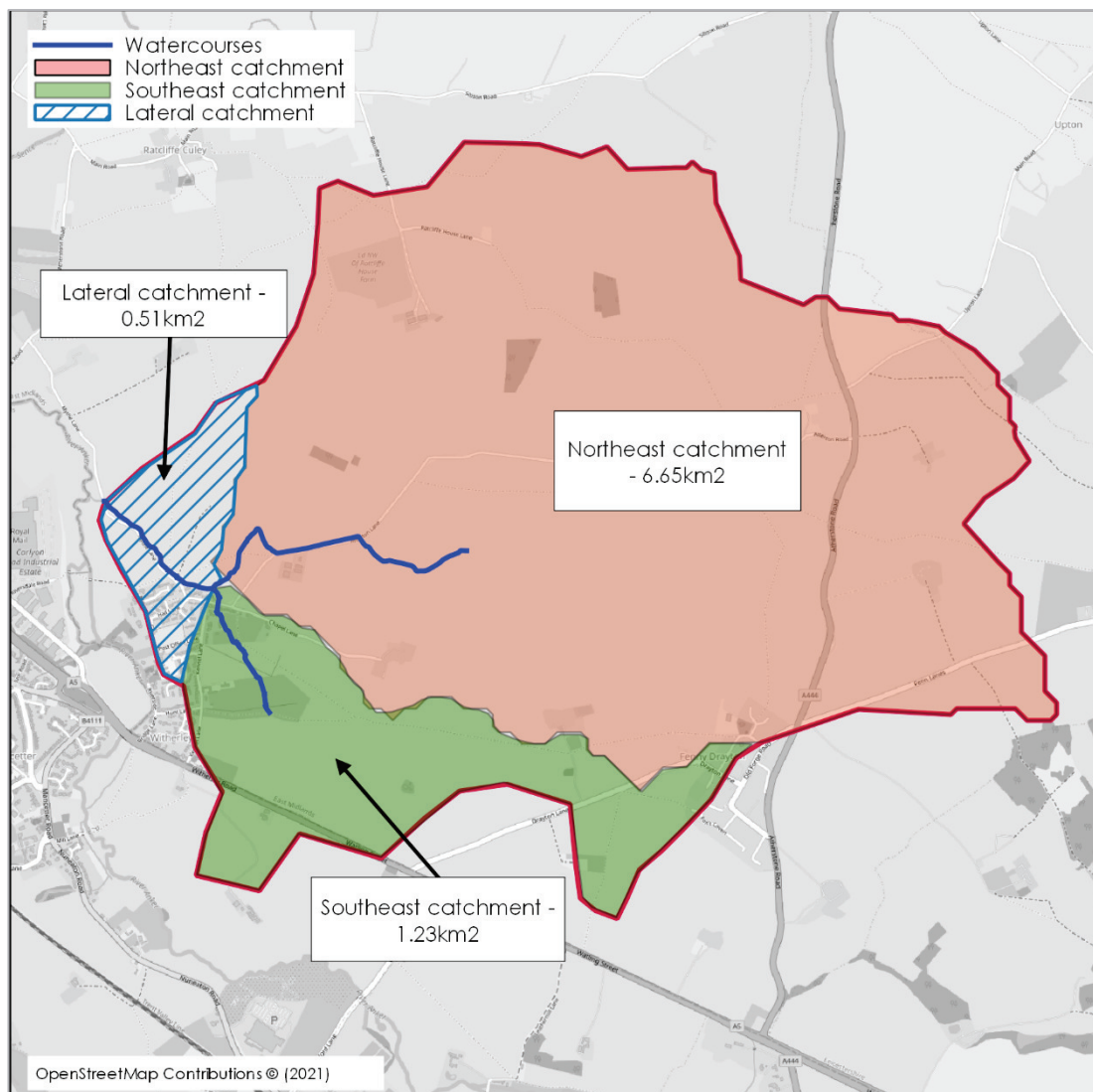


Figure 2-1 Hydrology Schematisation

Fenny Drayton Highway Flood Risk Management Scheme

- 2.2 In consultations with the EA it was identified that in 2014 a Flood Management Scheme was undertaken on the A5 in the upstream extents of the Southern Tributary's catchment.
- 2.3 Consultations with Highways England's drainage engineers revealed that the objective of the scheme was to resolve a localised flooding issue. It was reported that the flooding was triggered by the capacity of the drainage system being exceeded, which forced storm water to flow over the carriageway and through third party land before it entered the downstream ditch network.
- 2.4 The 2014 scheme was undertaken on a 380m stretch of the southbound carriageway of the A5 between the layby at Copper Kettle Café and the Drayton Lane junction. The works included replacing blocked/ damaged pipes, and regrading an adjacent ditch.

- 2.5 It was reported that the new pipe work and ditch have increased the capacity of the drainage system so that it can now hold a greater volume of storm water, thus reducing the probability of it being exceeded.
- 2.6 It was confirmed that the outfall location, pipe size and upstream drainage catchment were not altered, and that the overall pass-on flows and volumes are essentially unchanged. In previous correspondence with Highways England the EA confirmed that they are happy that the works would not affect downstream flood risk.
- 2.7 As the works are located a significant distance from the study site (900m), and they have not altered the catchment or increased pass on flows, it was not considered necessary to assess these minor works in any further detail.

Climate Change

- 2.8 In July 2021 the predicted future change in peak river flows were updated by the Environment Agency². These replaced the previous allowances applied to regionalised 'river basin districts'.
- 2.9 The Witherley Brook and River Anker catchment fall within the Tame, Anker and Mease Management Catchment. **Table 2.2** identifies the relevant peak river flow allowances.

Table 2.2 - Climate change allowances for the Tame, Anker and Mease Management Catchment

Allowance Category	Total potential change anticipated for '2020s'	Total potential change anticipated for '2050s'	Total potential change anticipated for '2080s'
Upper End	24%	30%	51%
Higher Central	15%	17%	30%
Central	10%	11%	22%

- 2.10 This hydraulic analysis will model the 'Central' (22%) allowance for the 2080s in line with the EA climate change guidance.

² <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>. Accessed August 2021.

3. HYDRAULIC MODEL BUILD

- 3.1 A dynamically linked 1D-2D modelling approach was adopted: the in-channel conditions and hydraulic structures were modelled within a one-dimensional (1D) ESTRY domain; and the out of bank flow routing and floodplain was modelled within a two-dimensional (2D) TUFLOW domain.

ESTRY: The 1D Model Domain

- 3.2 A cross-sectional watercourse survey of the Witherley Brook was completed in December 2015. It included the channel between the River Anker and Atterton Lane, the culvert under Atterton Lane, and a stretch of the southern tributary. The survey is included as **Appendix 2**.
- 3.3 The eastern and northern tributaries channels were not included within the hydraulic model, as their influence was to be account for by a hydrological inflow downstream of Atterton Lane.
- 3.4 Channel cross-sections were surveyed at regular intervals in locations which captured the general condition and shape of the open watercourses. The sections were truncated at top-of-bank, at what would be the interface with the 2D floodplain (thereby avoiding double counting the conveyance of the river corridor).
- 3.5 The channel was found to be well vegetated with in-channel weeds with sluggish flow throughout the majority of the surveyed reaches; this is illustrated within **Figure 3-1**. A Manning's 'n' roughness value of 0.070 was adopted to represent these conditions.



Figure 3-1 Example of Channel Conditions

- 3.6 The surveyed reach contained six culverted reaches/structures. Their location is shown in **Figure 3-2** and further details follow.



Figure 3-2 Location of hydraulic structures

1. **Mythe Lane Road Bridge** (NGR: 432318, 298044): twin 1m diameter culverts and an arch culvert. The brook immediately downstream of the bridge outfalls to the River Anker, and given the low lying nature of the road and the ability for it to be easily bypassed by the Anker's flood levels, this structure was omitted from the model. This will allow the River Anker flood wave to propagate freely upstream.



2. **WBBridge1 - Footbridge** (NGR: 432591, 297758): narrow and thin timber deck with supporting beams crossing the channel at bank top. Modelled as a bridge within ESTRY, with a weir over the top of the deck. Manning's 'n' adopted from adjoining river sections.



3. **WBBridge2 - Vehicular Access Bridge** (NGR: 432627, 297723): thin timber deck with supporting beams crossing the channel at bank top. Modelled as a bridge within ESTRY. The wider deck allowed flows over the top to be modelled within the 2D domain. Manning's 'n' adopted from adjoining river sections.



4. **WB_Culvert_1 – Culvert under Atterton Lane** (NGR: 432799, 297588). 1.086m to 0.792m diameter culvert modelled as a circular culvert within ESTRY. The smaller upstream diameter was adopted within the model. A Manning's 'n' of 0.018 was adopted to represent the concrete/glazed brick construction.



5. **WB_Culvert_2 – farm access culvert** (NGR: 432881, 297437). 0.688m to 0.527m diameter culvert modelled as a circular culvert within ESTRY. The smaller upstream diameter was adopted within the model. A Manning's 'n' of 0.018 adopted to represent the plastic construction, with some bed sediments.



6. **WB_Culvert_3 – culvert under upstream farm access track** (NGR: 432999, 297186). 0.382m to 0.327m diameter culvert modelled as a circular culvert within ESTRY. The smaller upstream diameter was adopted within the model. A Manning's 'n' of 0.018 adopted to represent the plastic construction, with some bed sediments.



2D TUFLOW: Floodplain Model Domain

Topography

- 3.7 Environment Agency 1.0m resolution LiDAR DTM (Digital Terrain Model) data was used as a base for the 2D floodplain; this has undergone a filtering process to remove buildings and vegetation to provide a bare earth ground model.