Appendix 16.1

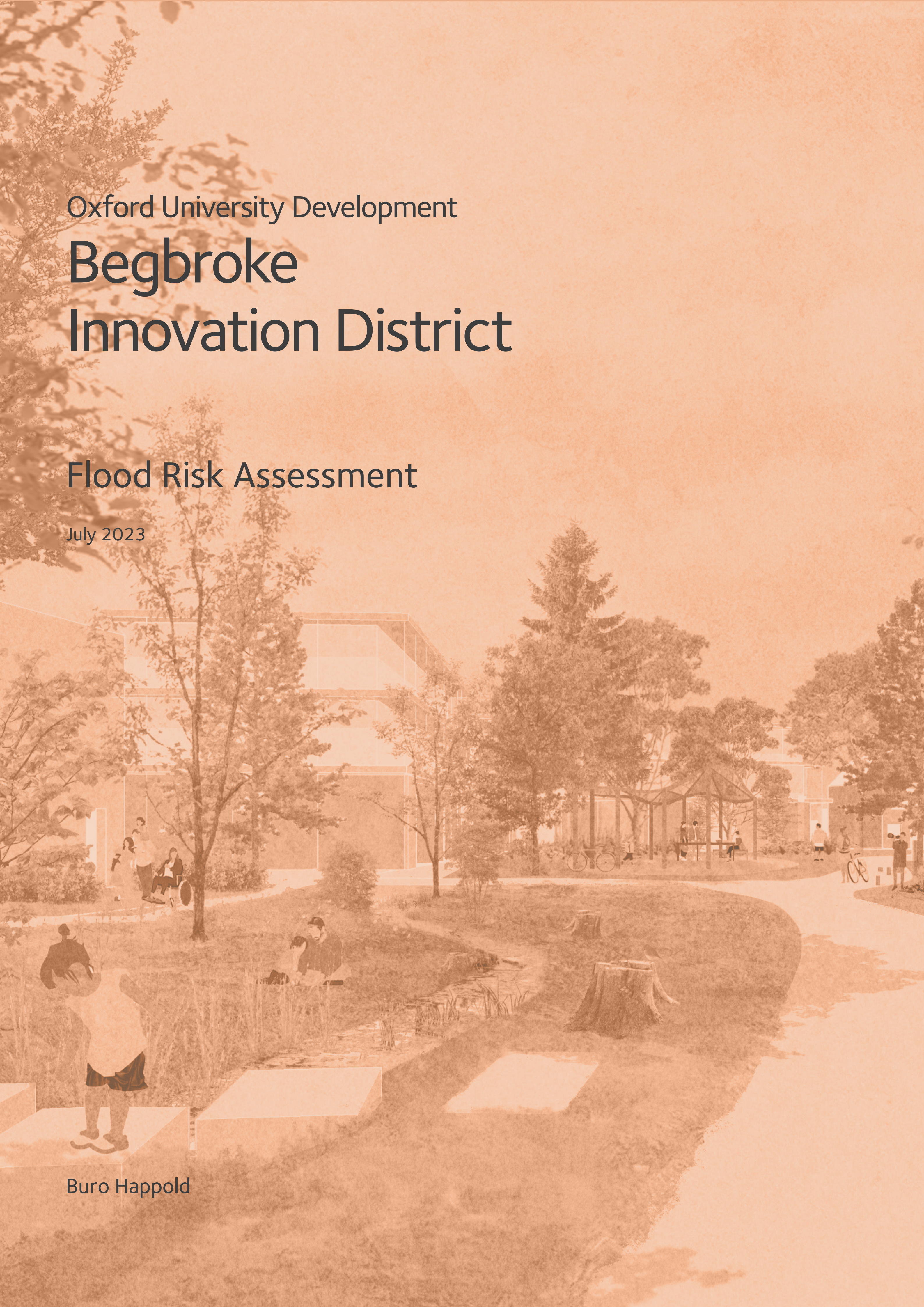
FLOOD RISK ASSESSMENT (INCLUDING DRAINAGE STRATEGY)

Oxford University Development

Begbroke Innovation District

Flood Risk Assessment

July 2023



Buro Happold

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Begbroke Innovation District

Flood Risk Assessment

BEG-BHE-XX-XX-RP-X-00001

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19 July 2023

Revision P04

Final

Revision	Description	Issued by	Date	Checked
P01	Draft Issue	GJ	11/05/23	DKR
P02	Second Draft Issue	GJ	02/06/23	DKR
P03	Third Draft Issue for Review	GJ	29/06/23	DKR
P04	Final Issue	GJ	19/07/23	DKR

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Report Disclaimer

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date	**19/07/2023**

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Glossary & Abbreviations

Term	Definition
Annual Exceedance Probability (AEP)	The Probability that a storm event will be exceeded in any given year.
CC	Climate Change
Discharge	The rate of flow of water measured in terms of volume per unit time
EA	Environment Agency
Flood Risk	The level of risk to personal safety and damage to property resulting from flooding due to the frequency or likelihood of flood events
Flood Risk Assessment (FRA)	An assessment of the flood risks to the Proposed Development over its expected lifetime and the possible flood risks to the surrounding areas, assessing flood flows, flood storage capacity and runoff
Flood Zones	The statistical chance of a flood event occurring in any one year, stated as a percentage. The National Planning Policy Framework identifies three flood zones that have been included in Section XX
Fluvial Flooding	Flooding related or connected to a watercourse (river or stream)
Groundwater	Water present within underground strata known as aquifers
Groundwater Flooding	Water occurring below ground in natural formations (typically rocks, gravels and sands)
Impermeable Surface	A surface that does not permit the infiltration of water and, therefore, generates surface water runoff during periods of rainfall
LLFA	Lead Local Flood Authority
OCC	Oxford County Council
OUD	Oxford University Development
SuDS	Sustainable Drainage Systems
TW	Thames Water

Executive Summary

This site-specific Flood Risk Assessment (FRA) has been prepared by Buro Happold on behalf of Oxford University Development Ltd (OUD) as part of the Outline Planning Application for the proposed Begbroke Innovation District (BID) in Begbroke, Kidlington, hereafter referred to as the 'Proposed Development'.

Subject		Findings
Site Description		The Site is located around the current site of Begbroke Science Park, Begbroke Hill, Begbroke, Kidlington (OX5 1PF). The Site is approximately 170 ha, with the majority of land being in agricultural use. Sandy Lane crosses the Site on an west-east alignment, joining the A44 to the west of the Site and Yarnton Road to the east of the Site. The Cherwell Valley railway line passes north-south through the Site. There are a number of watercourses on and adjacent to the site. Rowel Brook flows from west to east across the north of the Site and to the east, the Site is bounded by the Oxford Canal.
Proposal Description		The Proposed Development is a phased, mixed-use development which would encompass the expansion of the existing Begbroke Science Park, residential and associated amenity, education, and community uses.
Existing Flood Risk	Fluvial and Tidal	Baseline Hydraulic Modelling has been undertaken to produce flood mapping to provide more accurate definition of the flood zones than those provided by the EA flood maps. The Site is not at coastal flood risk. The majority of the Site is located within Flood Zone 1 and at low risk of flooding. Areas located in Flood Zone 2 and 3, which are at medium to high flood risk are located along the length of Rowel Brook, the parcel of land to the west of the Oxford Canal, in the North-West of the Site and around the Southern drainage ditch.
	Ground Water	There may be a risk of groundwater flooding in the lower lying areas around the perimeter of the Site due to shallow ground water levels. This has been considered in the design of the surface water drainage strategy with regards to the location and design of attenuation ponds and use of infiltration drainage. Hydrock have confirmed that through a review of the geology encountered on the Site during the investigation works, the areas where potential springs may occur is in the north-east area of the site; north-east of Rowel Brook. The ground water flood risk to the Site is therefore considered to be Low.
	Surface Water	The majority of the Site is subject to Very Low surface water flood risk. There are localised areas of ponding on the Site, which are classified as having Medium to High Risk of surface water flooding. These occur around the drainage channels to the south, around the east and southeast of the Site and also on the land adjacent to the Rowel Brook. These have been considered in the Site layout and the overall surface water drainage strategy and mitigations proposed where necessary.
	Sewers	The existing sewer network includes five active and two abandoned Thames Water sewers which cross the site. These have been flagged for diversion, with the proposed diversion routes being developed in collaboration with TW. Thames Water have confirmed that there is capacity within the sewer infrastructure for connection.
	Artificial Sources	According to the risk of flooding shown on the EA Reservoirs Map, a portion of the Site, mainly to the east/ south-east, is located within the maximum extent of flooding from reservoirs. The SFRA identifies a residual risk of flooding to the Site from overtopping of the Oxford Canal. It is noted that water overtopping from the canal in a more extreme event has been captured in the fluvial flood modelling. The overall flood risk from artificial sources is Low and no further mitigation is required.
Proposed Mitigation Measures		The key principle in the flood risk management strategy is to make space for water in developing the masterplan where possible. However, in the NW of the Site there is an existing overland flow route and measures to mitigate this risk are required. In this location a swale has been proposed to intercept, store and divert the overland flow around the Proposed Development. The proposed location of the Secondary School Site would be permissible following the NPPF guidance however OCC design criteria stipulate that no flooding can occur within the school site boundary for both the 1:100 year and the 1:1000 year event. Regrading has been proposed to ensure no flooding of the school site occurs. Flood storage within the red line boundary to the west

Subject	Findings
	of the school site is proposed to provide effective mitigation on a volume-for-volume basis so as to ensure there are no increases in flood risk outside of the red line boundary or to any development on site. The surface water drainage strategy for the Proposed Development will aim to replicate the predevelopment surface water runoff regime. This is achieved by capturing, filtering and harvesting (where possible) surface water as close to source as possible through source control SuDS features. The SuDS hierarchy will be used to design the Site drainage in the most sustainable way. Building upon OUD's vision for sustainable places. All storm events up to the 1 in 100-year storm event + 40% climate change allowance are proposed to be attenuated on site and discharge from the Site to the proposed outlet at the QBAR rate. The 1 in 1-year storm event will be retained to the corresponding greenfield event. In areas of the Site where the ground conditions allow for it, infiltration is promoted to reduce the volumetric discharge of surface water from the site. The Proposed Development is therefore considered to be at Low flood risk in light of these proposed mitigation measures.
Conclusion	With the proposed mitigation in place, the overall flood risk to the Proposed Development is Low.

1 Introduction

1.1 Background

This site-specific Flood Risk Assessment (FRA) has been prepared by Buro Happold on behalf of Oxford University Development Ltd (OUD) as part of the Outline Planning Application for the proposed Begbroke Innovation District (BID) in Begbroke, Kidlington, hereafter referred to as the 'Proposed Development'. This assessment has been developed in accordance with the National Planning Policy Framework (NPPF) (NPPF, 2021) and the Planning Practice Guidance (PPG) and considers potential flood risk to the Proposed Development from the following sources: tidal, fluvial, surface water, sewer, groundwater, artificial sources and failure of drainage infrastructure.

In order to comply with the NPPF and PPG, this FRA will identify the potential flood risks and demonstrate appropriate flood mitigation measures to ensure that the risk to the Site is acceptable for the level of development proposed.

1.2 Site Description

The Site is located on the current site of Begbroke Science Park, Begbroke Hill, Begbroke, Kidlington (OX5 1PF). BID is within the planning jurisdiction of the Cherwell District Council, North Oxfordshire, with the Lead Local Flood Authority (LLFA) being Oxfordshire County Council.

The Site is approximately 170 ha, of which ~80ha is developable. The Site is located approximately 6.7km north west of Oxford City centre, approximately 625m west of Kidlington village centre and close to the villages of Yarnton and Begbroke. Begbroke Science Park is located within the central northern portion of the Site. It comprises a number of one and two storey buildings which accommodate laboratories, engineering facilities and administrative buildings. Rushy Meadows, an SSSI (Site of Special Scientific Interest) is located just north of the east section of Rowel Brook, outside of the Site boundary.

The majority of the remainder of the Site is in agricultural use for arable farming. Sandy Lane crosses the Site on an appropriate west-east alignment, joining the A44 to the west of the Site and Yarnton Road to the east of the Site. The Cherwell Valley railway line passes through the Site on an approximate north-south alignment. A historical landfill site, known as Sandy Lane East, is located in the centre of the Site and is approximately 5.2ha in area.

The topography varies from 69mAOD to 60mAOD (as seen in Figure 2). The high point is close to the centre of the site, sloping down towards the watercourses to the north, east and south. The flatter areas are to the east and northwest of the site.

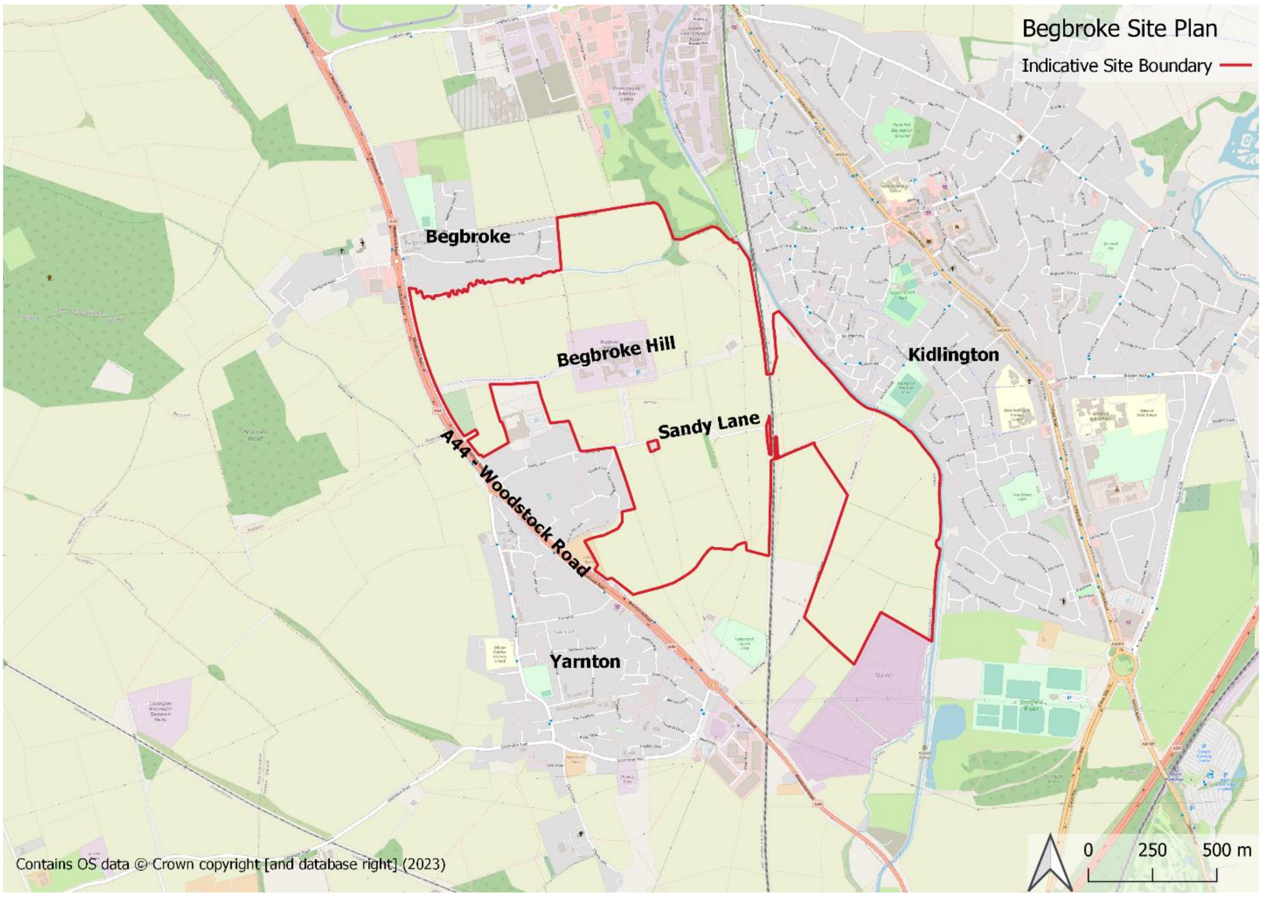

Figure 1 Site location map and red line boundary

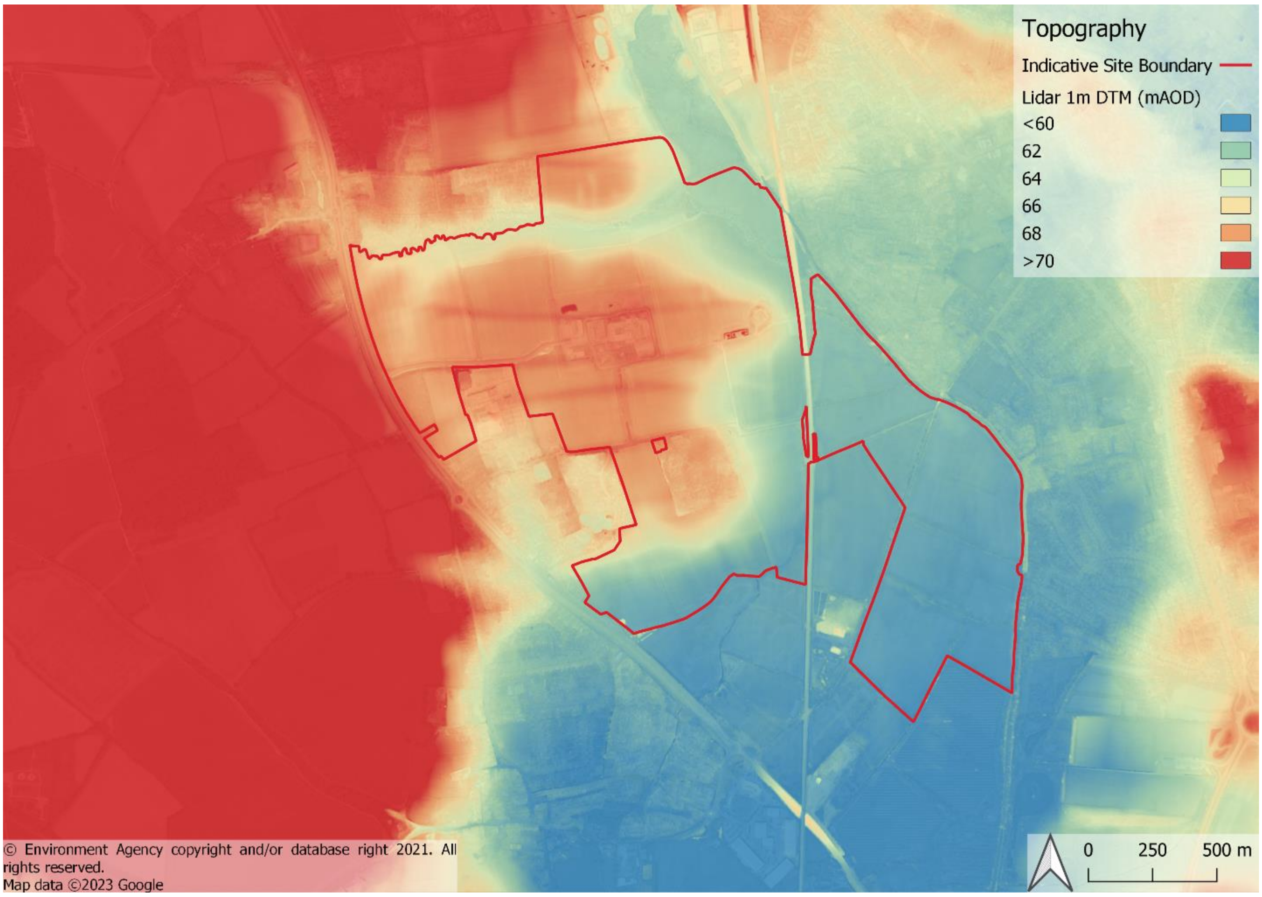

Figure 2 Topographic Lidar Data

1.2.1 Description of Watercourses

There are a number of watercourses on and adjacent to the site. These include the Rowel Brook, the Thrupp ditch, the Southern Drainage Ditch, the Eastern Drainage Ditches as well as other field ditches. To the east, the Site is bounded by the Oxford Canal.

The Rowel Brook flows in an easterly direction along the northern boundary of the Site before joining the Oxford Canal. The Oxford Canal then flows in a southerly direction to the east of the site.

There are a few drainage ditches that capture and convey surface water run-off from the site. These include the Southern Drainage Ditch that is classified as a Main River located to the south of the Site which flows towards Yarnton via a culvert under the A44. An existing culvert also crosses the railway line to the east of the site. It is understood that this culvert conveys flow from the Rowel Brook towards the Oxford Canal, but the outfall location has not been confirmed.

Figure 3 shows those watercourses on the Site which are designated as Main Rivers by the Environment Agency (EA), it is noted that the Oxford Canal is not a designated Main River.

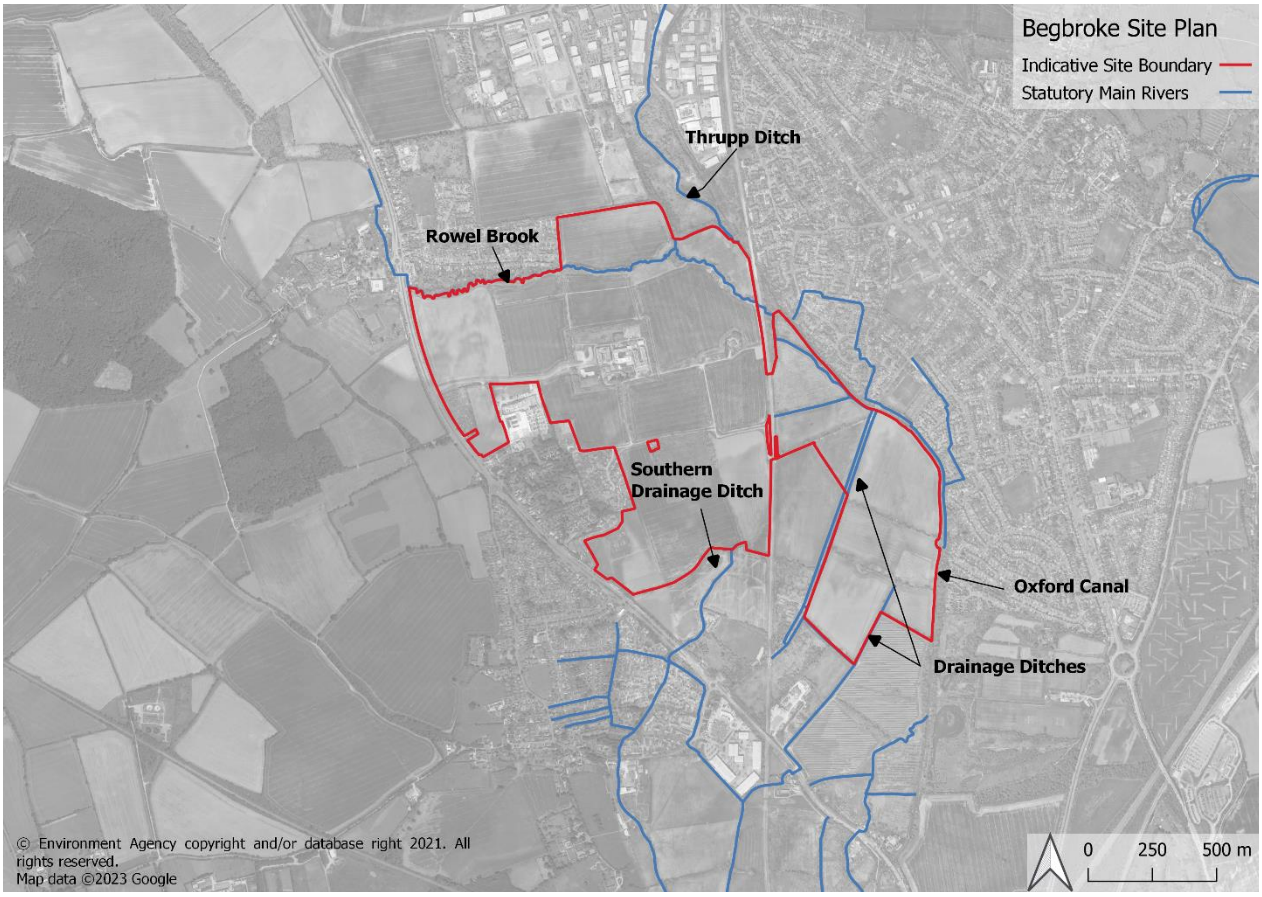

Figure 3 Site Map with key watercourses highlighted and EA Statutory Main Rivers shown

1.3 Proposed Development

The Proposed Development is a phased, mixed-use development which would encompass the expansion of the existing Begbroke Science Park, residential and associated amenity, education, and community uses. The Description of Development is as follows:

- Up to 215,000 square metres gross external area of residential floorspace within Use Class C3/C4 and large houses of multiple occupation (Sui Generis);
- Supporting social infrastructure including secondary school/primary school(s) (Use Class F1); health, indoor sport and recreation, emergency, and nursery facilities (Class E(d)-(f))
- Supporting retail, leisure and community uses, including retail (Class E(a)), cafes and restaurants (Class E(b)), commercial and professional services (Class E(c)), local community uses (Class F2), and other local centre uses within a Sui Generis use including public houses, bars and drinking establishments (including with expanded food provision), hot food takeaways, venues for live music performance, theatre, and cinema.
- Up to 155,000 square metres gross external area of flexible employment uses including research and development, office and workspace and associated uses (Use E(g)), industrial (Use Class B2) and storage (Use Class B8) in connection with the expansion of Begbroke Science Park;
- Highway works, including new vehicular, cyclist and pedestrian roads and paths, improvements to the existing Sandy Lane and Begbroke Hill road, a bridge over the Oxford Canal, safeguarded land for a rail halt, and car and cycle parking with associated electric vehicle charging infrastructure;

- Landscape and public realm, including areas for sustainable urban drainage systems, allotments, biodiversity areas, outdoor play and sports facilities (Use Class F2(c));
- Utility, energy, water, and waste water facilities and infrastructure;
- together with enabling and associated works, including temporary meanwhile uses.

The Parameter Plan showing development areas and land uses and the illustrative masterplan are shown below in Figure 4 and Figure 5 respectively.

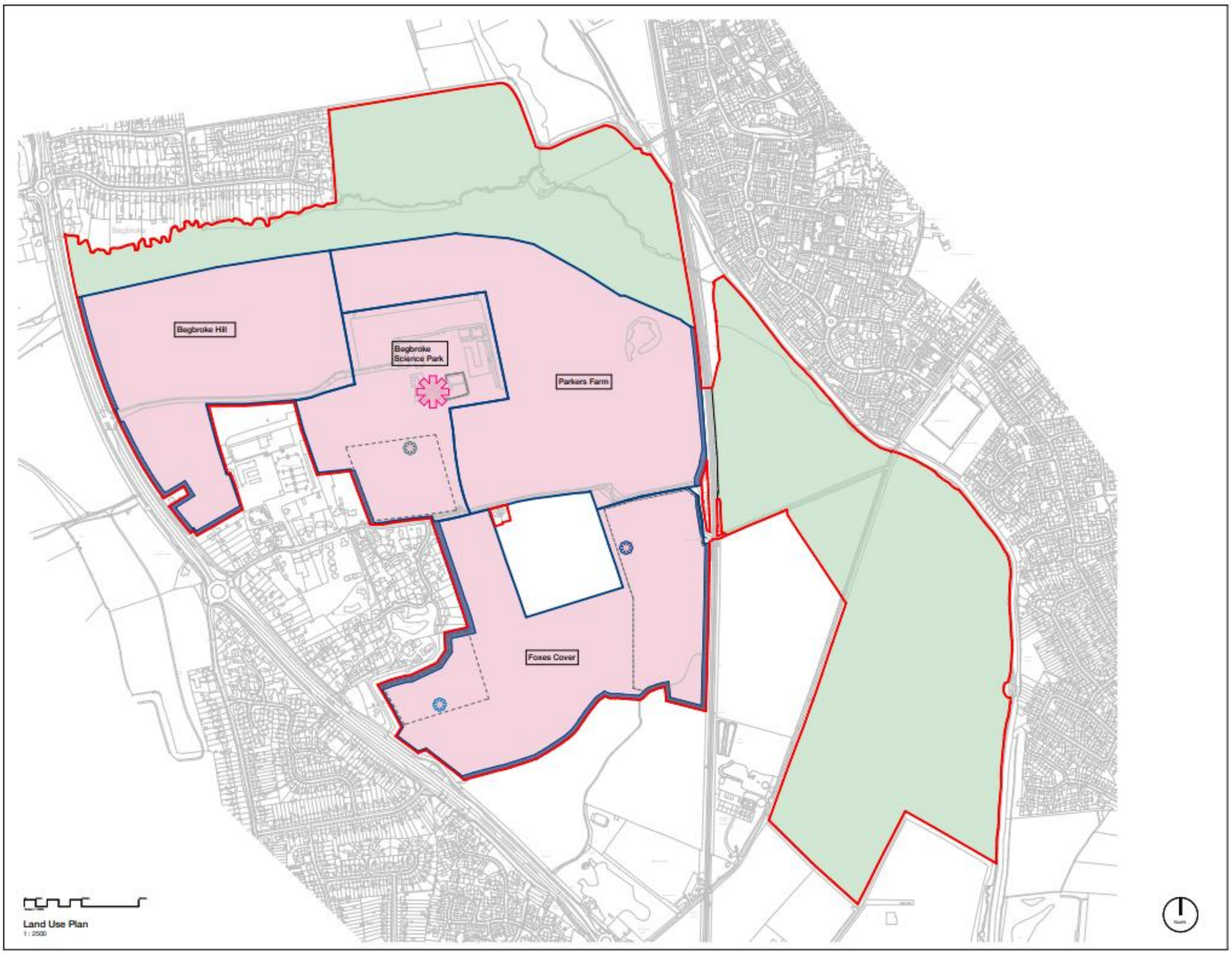

Figure 4 Parameter Plan - Development Zones (Drawing No. BEG-HBA-SW-ZZ-SK-A-SK81) (Hawkins Brown, 15/05/23)

Figure 5 Illustrative Masterplan (Hawkins Brown)

2 Planning Context

2.1 Overview

This site-specific FRA has been prepared in accordance with the policies, legislation and guidance applicable to the Development provided by UK national and local governments. This policy and guidance has been produced to inform flood related decision-making in all stages of development. The documents applicable to the Proposed Development are:

- National Planning Policy Framework (NPPF) (July 2021);
- National Planning Policy Framework Planning Practice Guidance (Updated: 24 June 2021);
- Cherwell Level 1 Strategic Flood Risk Assessment (SFRA) Update (May 2017);
- Cherwell Level 2 SFRA (May 2017);
- Cherwell Level 2 SFRA Addendum (February 2018);
- Oxfordshire County Council Local Flood Risk Management Strategy (LFRMS) (undated);
- Oxfordshire County Council Local Standards and Guidance for Surface Water Drainage on Major Development in Oxfordshire (December, 2021);
- Oxfordshire County Council Key Design Criteria for Secondary School Sites (undated);
- The Cherwell Local Plan 2011 – 2031 (July 2015); and
- The Cherwell Local Plan Part 1 Partial Review (September 2020).

2.2 National Planning Policy Framework

2.2.1 Flood Risk Assessment

The NPPF aims to avoid inappropriate development in areas at the highest risk of flooding. The Planning Practice Guidance to the NPPF contains a series of tables that help identify the risk of flooding to a development, see Appendix A for the tables. A summary is provided below:

- Table 1 (Appendix A) defines four Flood Zones based on the annual probability of river or sea flooding;
- Table 2 (Appendix A) identifies specific land use types for each of the five flood risk vulnerability classifications (Essential Infrastructure, Highly Vulnerable, More Vulnerable, Less Vulnerable and Water Compatible Uses). For example, office buildings are classified as Less Vulnerable; and
- Table 3 (Appendix A) identifies where development is appropriate for each flood risk vulnerability classification and whether the Exception Test is required.

The Flood Zones are defined in the NPPF as follows:

Flood Zone 1 Low Probability:

< 1 in 1,000 annual probability of river or sea flooding in any given year (<0.1% Annual Exceedance Probability (AEP))

Flood Zone 2 Medium Probability:

Between 1 in 100 and 1 in 1,000 annual probability of river flooding in any year (1% - 0.1% AEP), or Between 1 in 200 and 1 in 1,000 annual probability of sea flooding in any year (0.5% - 0.1% AEP).

Flood Zone 3a High Probability:

> 1 in 100 annual probability of river flooding in any year (>1% AEP), or

> 1 in 200 annual probability of sea flooding in any year (>0.5% AEP).

Flood Zone 3b Functional Floodplain:

> 1 in 30 annual probability of flooding in any year (3.3% AEP).

2.2.2 Flood Risk & Vulnerability Classification

The PPG of the NPPF outlines the Vulnerability Classifications of land use types and building uses. The Proposed Development is comprised of residential, commercial and academic uses. In accordance with the EA, the vulnerability classifications for the Proposed Development are described in Table 1 below:

Table 1 Proposed land uses on the Site with their associated vulnerability classification

Land Use	Vulnerability Classification
Residential	More Vulnerable
Educational Establishments	More Vulnerable
Commercial	Less Vulnerable
Primary Substation	Essential

2.2.3 Climate Change

Allowances for the predicted effects of climate change should be considered when preparing site-specific flood risk assessments. This is the principal means of ensuring that a development is designed with appropriate resilience.

The NPPF guidance contains sensitivity ranges that are recommended to be applied to peak rainfall intensities, peak river flows, sea level rise, offshore wind speeds and extreme wave heights. The general trend is for each parameter to increase in the future, which in turn increases the risk of flooding to any site.

Peak river flow allowances show the anticipated changes to peak flow by management catchment. Based on the EA's peak river flow map, the following climate change allowances should be considered for the Site as it is part of the Gloucestershire and the Vale Management Catchment:

Table 2 Gloucestershire and the Vale management catchment peak river flow allowances (EA, 2021)

Period of CC	Central (50th percentile)	Higher (70th percentile)	Upper (95th percentile)
Total potential change anticipated for the '2020s' 2015 to 2039	11%	17%	33%
Total potential change anticipated for the '2050s' 2040 to 2069	11%	19%	43%
Total potential change anticipated for the '2080s' 2070 to 2115	**26%**	**41%**	84%

The latest guidance states that in flood zones 2 or 3a all development types should use the Central Allowance except for *Essential Infrastructure* which should use the Higher Allowance.

Therefore, the Minimum Design Flood Event (DFE) for the Site for fluvial flooding has been identified as the 1 in 100 year including 26% climate change allowance, based on NPPF guidance. However, given the sustainability aspiration to increase climate resilience further, the Higher Allowance stated in the table above has been considered for all development types.

The following peak rainfall allowances should be considered for the Site for a 1% annual exceedance rainfall event:

Table 3 Gloucestershire and the Vale management catchment 1% annual exceedance rainfall event allowances (EA, 2021)

Period of CC	Central (50th percentile)	Upper (95th percentile)
Total potential change anticipated for the '2050s' 2040 to 2069	20%	40%
Total potential change anticipated for the '2080s' 2070 to 2115	25%	40%

It is recommended by the guidance that both the central and upper-end allowances are assessed in order to understand the range of the impact. The guidance further notes that the following considerations be made to decide the allowances that are adopted to inform the flood risk management strategy for a development:

- Likely depth, speed and extent of flooding for each allowance of climate change over time, considering the allowances for the relevant epoch (2020s, 2050s and 2080s);
- Vulnerability of the proposed types of development or land use allocations to flooding;
- 'Built-in' resilience measures used, for example, raised floor levels; and
- Capacity or space in the development to include additional resilience measures in the future, using a 'managed adaptive' approach.

Given the proposed land use types and the design life of the residential being a minimum of 100 years, an allowance for a 40% increase in peak rainfall intensity is being used in the Surface Water Drainage Strategy, prepared by Buro Happold.

2.3 Cherwell District Council Local Plan

The Site falls within the administration of Cherwell District Council which has created the Cherwell Local Plan 2011-2031 which was adopted in 2015. A Partial Review for Oxford's unmet housing need was then published in September 2020. The Local Plan guides the changing use of land in the district through long term strategic spatial visions, with strategic spatial framework and policies to help deliver this vision. The Proposed Development is located in PR8 and neighbours PR3a, PR7b and PR9.

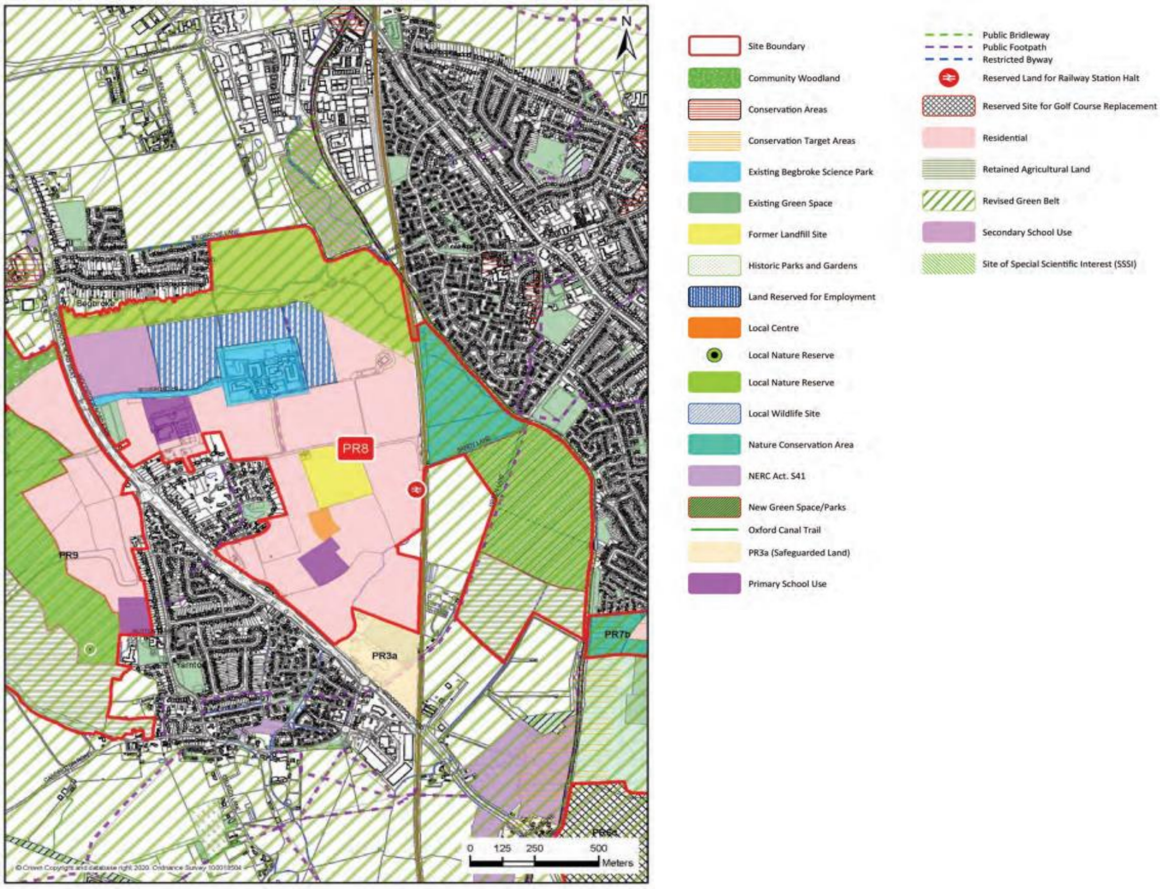

Figure 6 PR8 Local Plan Designation (The Cherwell Local Plan 2011-2031 (Part1) Partial Review (September 2020))

Below are the relevant policies from the Local Plan that have to be adhered to in developing the site's flood risk and drainage strategy:

- ESD 1: Mitigation and Adapting to Climate Change
- ESD 6: Sustainable Flood Risk Management
- ESD 7: Sustainable Drainage Systems (SuDS)
- ESD 8: Water Resources
- ESD 16: The Oxford Canal

Policy ESD 6 in the Cherwell District Local Plan presents the policy around sustainable flood risk management. The key points have been summarised below:

- The Council will manage and reduce flood risk in the district through using a sequential approach to development, locating vulnerable developments in areas at lower risk of flooding.
- Development will only be permitted in areas of flood risk when there are no reasonably available sites in areas of lower flood risk and the benefits of the development outweigh the risks from flooding.
- Opportunities will be sought to restore natural river flows and floodplains, increasing their amenity and biodiversity value.
- Flood risk assessments should assess all sources of flood risk and demonstrate that:
    - There will be no increase in surface water discharge rates or volumes during storm events up to and including the 1 in 100 year storm event with an allowance for climate change (the design storm event).
    - Developments will not flood from surface water up to and including the design storm event or any surface water flooding beyond the 1 in 30 year storm event, up to and including the design storm event will be safely contained on site.
- This section sets out that where there is no EA modelled data available from the EA, a Level 3 FRA including hydraulic modelling may be required for sites in close proximity to the Rowell Brook or the River Cherwell.

2.4 Strategic Flood Risk Assessment

SFRAs are required to be carried out by Local Authorities to guide developers on the authority's strategies to avoid, reduce and manage flood risk. A Level 1 and 2 SFRA has been carried out for Cherwell District Council in 2017, with an addendum to the Level 2 SFRA in 2018. The addendum provides a more detailed analysis of the fluvial flood risk within the PR8 land allocation, although still in lieu of any detailed modelling. This analysis aims to provide confidence that the proposed land uses within PR8 are likely to be deliverable, with respect to climate change.

The Cherwell Council's SFRAs consider the risk of flooding from the following potential sources:

- Fluvial (rivers);
- Tidal;
- Surface water;
- Groundwater; and
- Sewers.

The risk of flooding to the Proposed Development from each source listed above will be assessed in Section 3.

2.5 Design Criteria for Secondary Schools

The OCC's document which outline's key design criteria for Secondary School Sites notes the following requirements relevant to flood risk:

- No part of a school site shall be located on Flood Zones 2 or 3;
- No runoff or surface water from adjoining land will be accepted;
- Any ditches shall be infilled prior to site transfer.

These criteria have been considered within the masterplanning, assessment of flood risk and any consequent mitigation required.

2.6 Consultation

Consultation has been undertaken with the EA, LLFA (OCC) and CRT in relation to flood risk and mitigation strategies. The consultation has been undertaken as a combination of email and telephone correspondence.

Email correspondence with the EA advised that the current hydraulic modelling (which the EA flood maps are based on) is likely to be based on JFLOW data, which is not suitable for this site-specific FRA. The EA instructed that detailed hydraulic modelling is required to support the Outline Planning Application.

Following this instruction, a meeting was held with representatives from the EA and OCC on 16th November 2022. The key objectives of this meeting were to:

- Agree the methodology to be used to define the fluvial flood extents for the project; and
- Receive flood risk pre-application advice and comments on strategy and the Proposed Development.

A Technical Note with the proposed methodology for the detailed hydraulic modelling was prepared and shared with the EA and OCC prior to the meeting. Table 4 gives a summary of the key items discussed in consultation with each Statutory Consultee.

Table 4 Summary of Consultation comments and design actions

Consultee	Key Theme	Consultee Comments/ Considerations
EA	Detailed Hydraulic Modelling Methodology	• It was requested that the technical note be updated to include strong justification for each assumption within the proposed methodology. This updated methodology statement was shared with the EA and LLFA 02/12/22 and is included in Appendix B for reference. • EA noted the importance of capturing all surface water flows which might enter the watercourses in the hydraulic model and that the interaction between surface water and fluvial flows is carefully considered. • The EA requested justification for the assumption that the Oxford Canal forms a hydrological barrier to demonstrate that there is no fluvial flooding from the Canal onto the Site due to surface water flows from Kidlington.
	Climate Change Allowances	• It was recommended that the ‘Central’ allowance of 26% be tested as well as the ‘Higher’ allowance of 41% for peak river flow allowances to check that Infrastructure classified as ‘Essential’ is not impacted.

Consultee	Key Theme	Consultee Comments/ Considerations
	Design Flood Event (DFE)	• The EA confirmed that it is appropriate to treat the 1 in100 with 26% allowance for climate change as the Design Flood Event (DFE) for the Site based on the 'More vulnerable' uses for the site. • Consideration needs to be given on whether the infrastructure on site is classified as 'Essential Infrastructure'. This should be considered as any infrastructure that is required to function during a flood and which serves a wider network other than the Site itself. The DFE for 'Essential Infrastructure' would be the 1 in 100 with 41% allowance for climate change.
	Finished Floor Levels (FFLs)	• EA confirmed a 300mm freeboard should be applied on top of the DFE level if permittable development located in Flood zone 2 or 3. • If development is in Flood Zone 1, a freeboard is not required to be applied. Although it was suggested to include this 300mm freeboard above the DFE level.
	Safe Access and Egress	• EA noted that this is often a critical matter on development sites and that features crossing the watercourses should be carefully considered. Bridge soffit levels would need to be designed to be above the DFE level with the addition of an appropriate freeboard. • EA noted that any land raising in the floodplain required to facilitate these crossings will need to demonstrate that the proposals do not increase flood risk and any solutions are feasible. • Once the flood extents have been defined, the impact of bridges and associated earthworks will need to be assessed.
OCC	Historic Flooding	• Information on historic flooding has been requested, OCC not aware of any records of flood risk in the vicinity of the site.
	8m easement	• Confirmation has been requested as to the LLFA's guidance on the requirement of an 8m easement from top of bank on the ordinary watercourses of the Site and what would be required as part of obtaining consent for works along these ditches. At the time of publishing this report, no response had been received on this matter.
	Surface Water Drainage Strategy	• At the time of publishing this report, the meetings to date have been used to present the overarching principles and the key engineering constraints to the SWD strategy. The LLFA confirmed the approach to restrict discharge rates from the Site to QBAR runoff rates. • Further liaisons will be had with the LLFA as the project develops to ensure that local guidelines and design requirements are met.

Consultee	Key Theme	Consultee Comments/ Considerations
CRT	Oxford Canal	• Confirmation that there are no current outfalls/ discharge points between Lock 42 and 44 (Information included in Appendix C). • Control levels given for the pounds above Lock 43 and 44, in the vicinity of the site. • Information on historic flooding has been requested multiple times, no response has been received at time of issue.

It is noted that as of the end of July 2023, Buro Happold have received no comment from the EA on the Hydraulic Modelling Strategy Technical Note.

3 Appraisal of Existing Flood Risk

3.1 Overview

This section evaluates the sources of flood risk to the existing Site. In this section the following sources of flood risk are evaluated:

- Historic Flooding
- Flooding from rivers (fluvial);
- Flooding from the sea (tidal);
- Flooding from surface water runoff (pluvial) and sewer surcharge;
- Flooding from groundwater; and
- Flooding from artificial sources.

3.2 National Planning Policy Framework

3.2.1 Flood Risk Zone Classification

The EA ‘Flood Map for Planning (Rivers and Sea)’ indicates that the Site lies within the three Flood Zones as shown in Figure 7, as follows:

- The majority of the Site sits within Flood Zone 1;
- Areas either side of the Rowel Brook across the north of the Site are in Flood Zone 2 and Flood Zone 3a;
- A large proportion of the east of The Site are in Flood Zone 2 and Flood Zone 3a.

There is no risk of tidal flooding at the Site.

The Environment Agency flood maps do not include an allowance for climate change and it is noted in the Level 2 SFRA that the drainage ditch at the south of the Site is unlikely to have been hydraulically modelled if its catchment area is $<3km^2$. This drainage ditch is culverted underneath the A44. There is a potential risk that if this culvert became blocked or the capacity was exceeded, that water could back up onto The Site and create localised flooding.

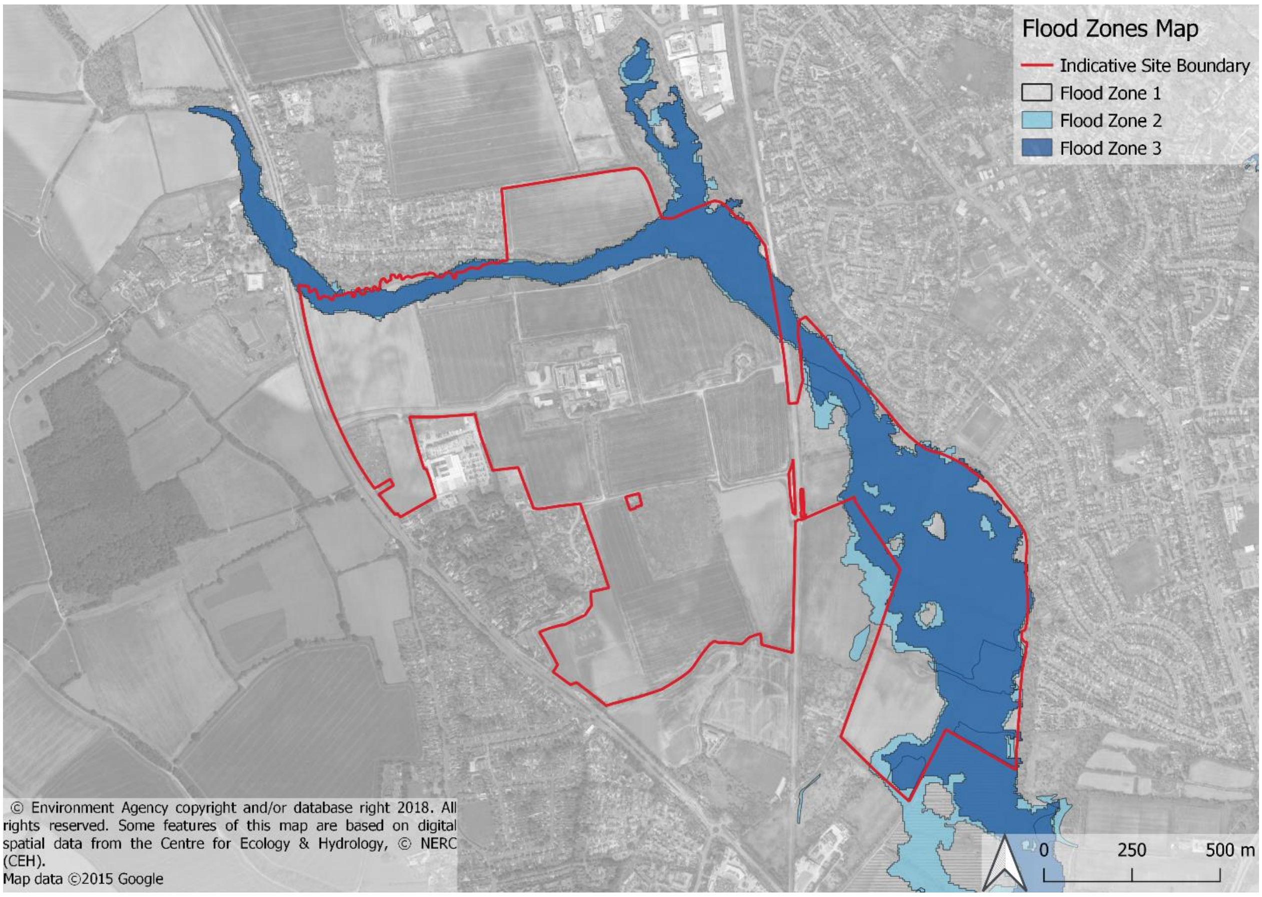

Figure 7 EA flood maps for planning shows present day flood zones

3.3 Historic Flooding

The EA Historical Flood Map illustrates small areas to the east of the railway line that have experienced historical flooding (Figure 8). The Level 2 SFRA Addendum identifies that this is as a result of fluvial flooding. The mapping also indicates that there have been a further four reported incidents of fluvial flooding, from ordinary watercourses, within 200 m of the Site.

The Level 2 SFRA Historic Flooding Incidents Map for the Site records 6 flooding incidents reported to the LLFA regarding drainage issues, however all of which are outside of the Site boundary.

Further consultation has been had with the EA, LLFA, CRT and Thames Water, with all parties sharing no further known historic flooding events in or in the locality of the Site.

Yarnton Flood Group have been engaged with as part of wider consultation for the Proposed Development. Discussions have been held with the Yarnton Flood Group and Begbroke Parish Council by OUD in order to understand both historical and current flooding issues observed in the local community. Local mapping was provided by Yarnton Flood Group which indicates that numerous sources of flood risk coupled with hydraulic capacity issues in the local drainage network combine to cause flooding to the community.

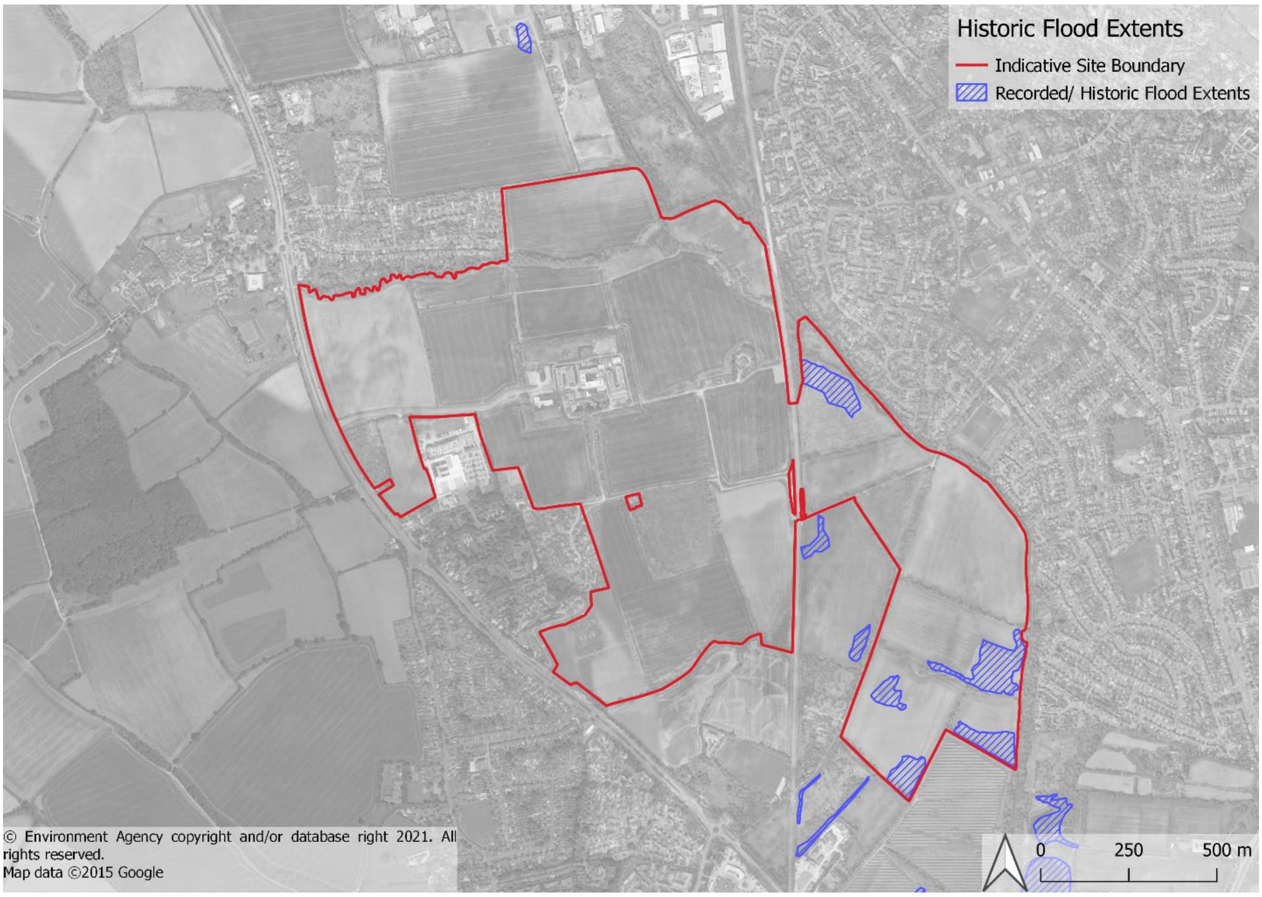

Figure 8 EA flood map showing historic flood event

3.4 Flood Risk to the Development Site

3.4.1 Fluvial and Tidal Flooding

Tidal flooding occurs when particularly high tides coincide with storm surges driven by low atmospheric pressure events causing localised raising of sea levels. It is noted from the EA flood maps and the SFRAs that the Site is not at risk of tidal flooding.

Fluvial flooding occurs when sustained or intense rainfall events increase the flow in rivers causing the water level to rise above the level of the banks and into the surrounding areas. The watercourses on site and their flow direction are noted in the Site description.

As advised by the EA, detailed hydraulic modelling has been undertaken to define the flood extents for the following key design events, with the 1 in 100-year event representing the Flood Zone 3 extent and the 1 in 1000-year event representing the Flood Zone 2 extent:

Table 5 Fluvial events simulated in the Baseline Modelling

Fluvial Events	AEP	Epoch	Scenario	Uplift
1 in 30 year	3.33%	Present		0%
1 in 100 year	1%	Present		0%

Fluvial Events	AEP	Epoch	Scenario	Uplift
1 in 100 year + CC	1%	2080s	Central	26%
1 in 100 year + CC	1%	2080s	Higher	41%
1 in 1000 year	0.1%	Present		0%

Full details of the modelling undertaken can be found in Appendix D. The baseline flood extents are shown in Figures 9-12 for the fluvial events noted above in Table 5. The baseline flood depth maps are provided for all fluvial events within Appendix D.

The modelling indicates that the majority of the Site is outside of all flood events.

The key areas at flood risk in all return events are:

- Sections of the Site along the length of Rowel Brook; and
- The parcel of land immediately to the west of the Oxford Canal.

In the higher order events, flood risk is also present:

- In the North-West of the Site, owing to water overtopping Woodstock Road and flowing in a north-easterly direction to Rowel Brook;
- Around the Southern drainage ditch due to a capacity issue within the ditch; and
- To the east of the site, close to Oxford Canal. This flooding is believed to be due to capacity issues in the Eastern drainage ditches. Much of the surface water from the Site is routed through these, however they do not appear to have the capacity to convey the flows in the more extreme events considered.

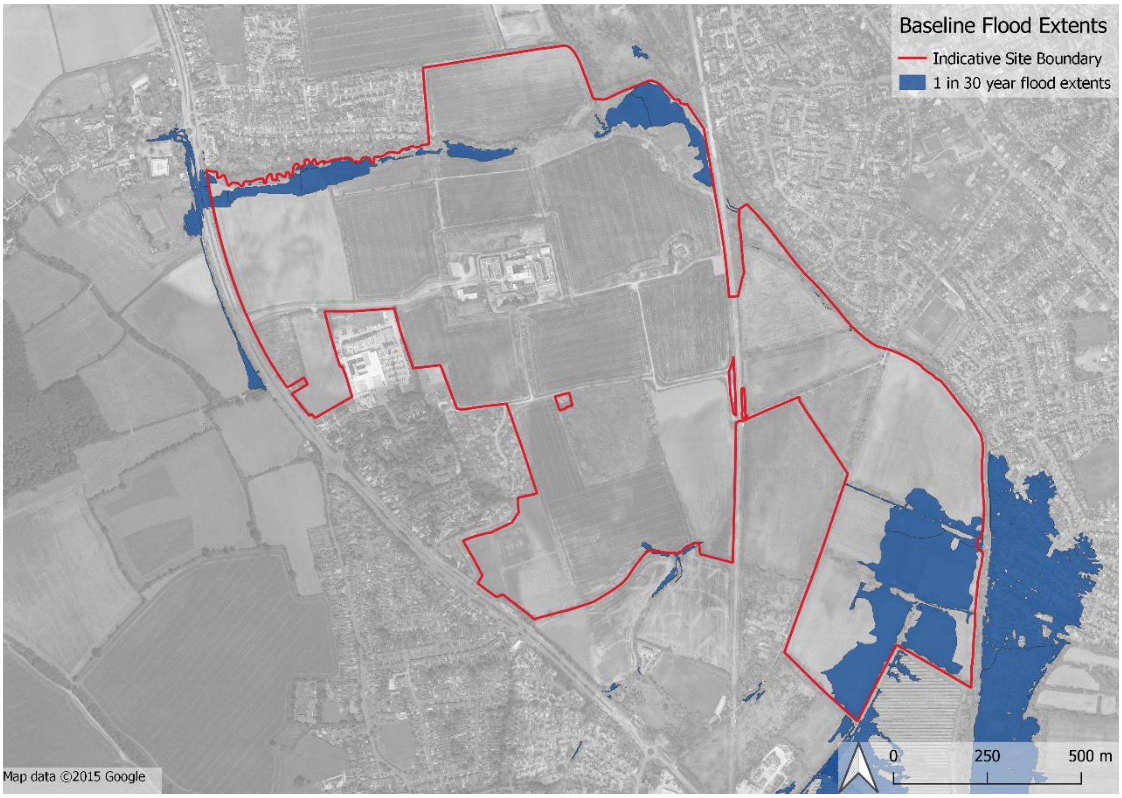

Figure 9 Baseline Fluvial Modelling Results – 1 in 30 year flood extents

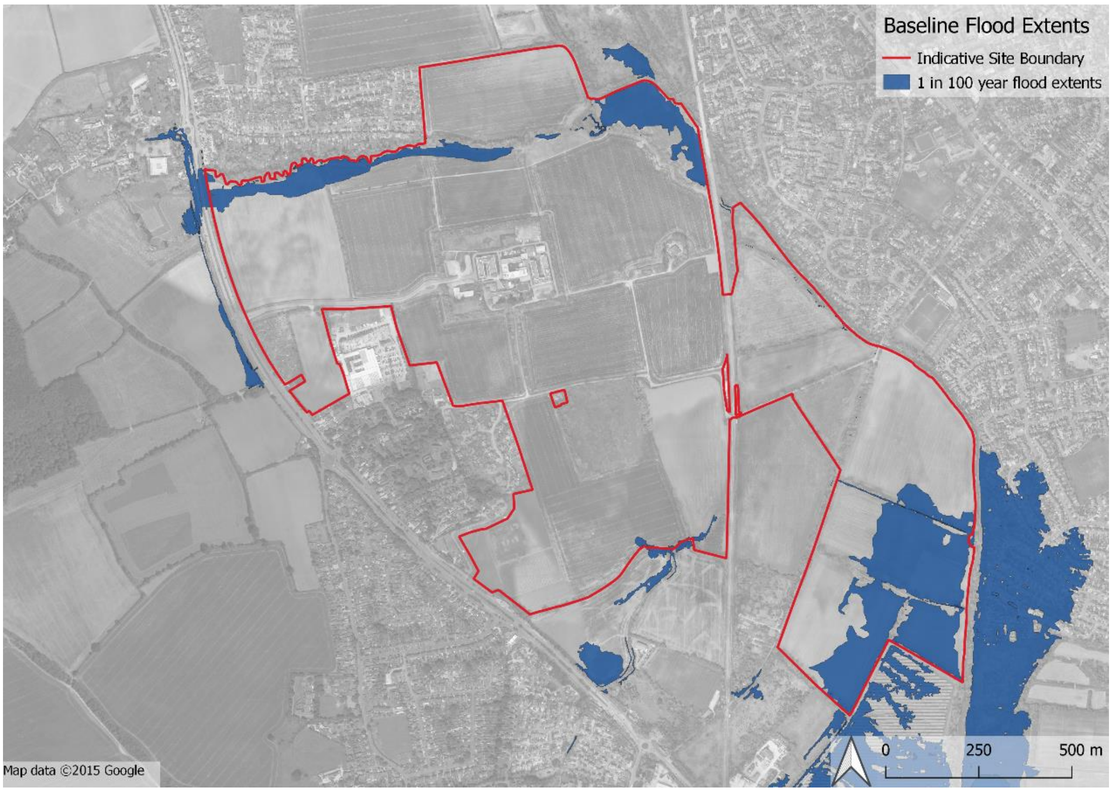

Figure 10 Baseline Fluvial Modelling Results – 1 in 100 year flood extents

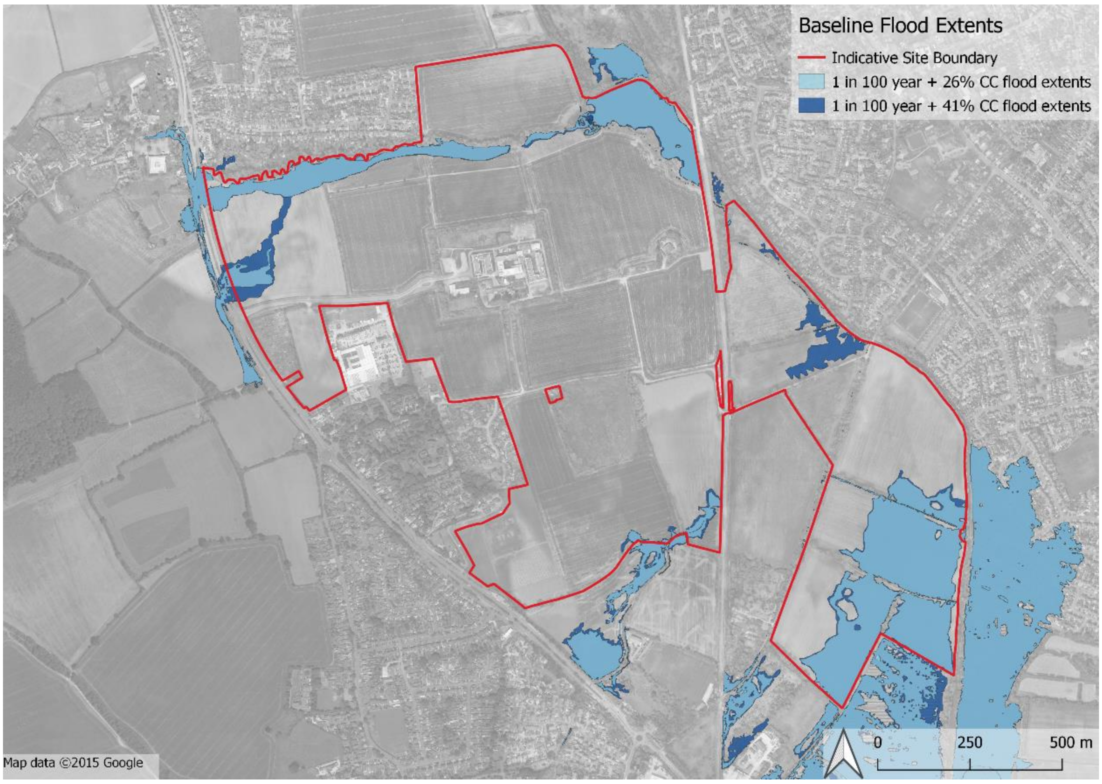

Figure 11 Baseline Fluvial Modelling Results – 1 in 100 year + 26% and 41% CC flood extents

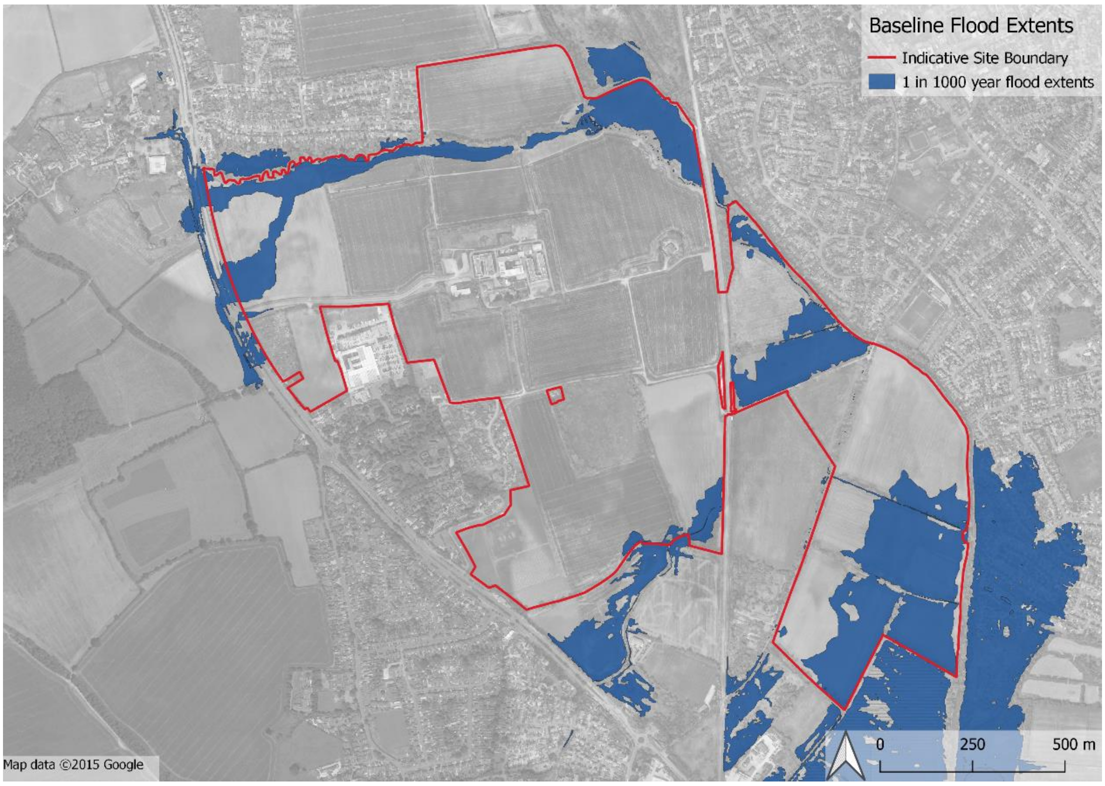

Figure 12 Baseline Fluvial Modelling Results – 1 in 1000 year flood extents

3.4.2 Surface Water Flooding

Surface water flooding occurs when intense rainfall is unable to naturally soak into the ground due to impermeable ground covering such as concrete or tarmac, or due to low permeability ground conditions preventing infiltration. This excess surface water can flow through built-up areas and open space and pond in lower-lying areas causing localised flooding.

The EA Surface Water Flood Maps show that most of the Site is subject to Very Low (between 0.1% and 1% AEP) surface water flood risk. There are localised areas of ponding on the Site, which are classified as having Medium (between 1% and 3.3% AEP) to High Risk (>3.3% AEP) of surface water flooding. These occur around the drainage channels to the south, around the east and southeast of the Site and also on the land adjacent to the Rowel Brook.

It is noted that no climate change allowance is considered in the below surface water flood mapping. Climate change will however be considered in the design of the surface water drainage strategy.

The baseline surface water flood risk to the Site is classified as medium. The map below shows some overlap between the risk of stormwater flooding and the baseline flood extents identified by the hydraulic modelling. However, development of the Site and the proposed surface water drainage strategy will mitigate any further risk of surface water flooding as a result of on-site rainfall in the design flood event.

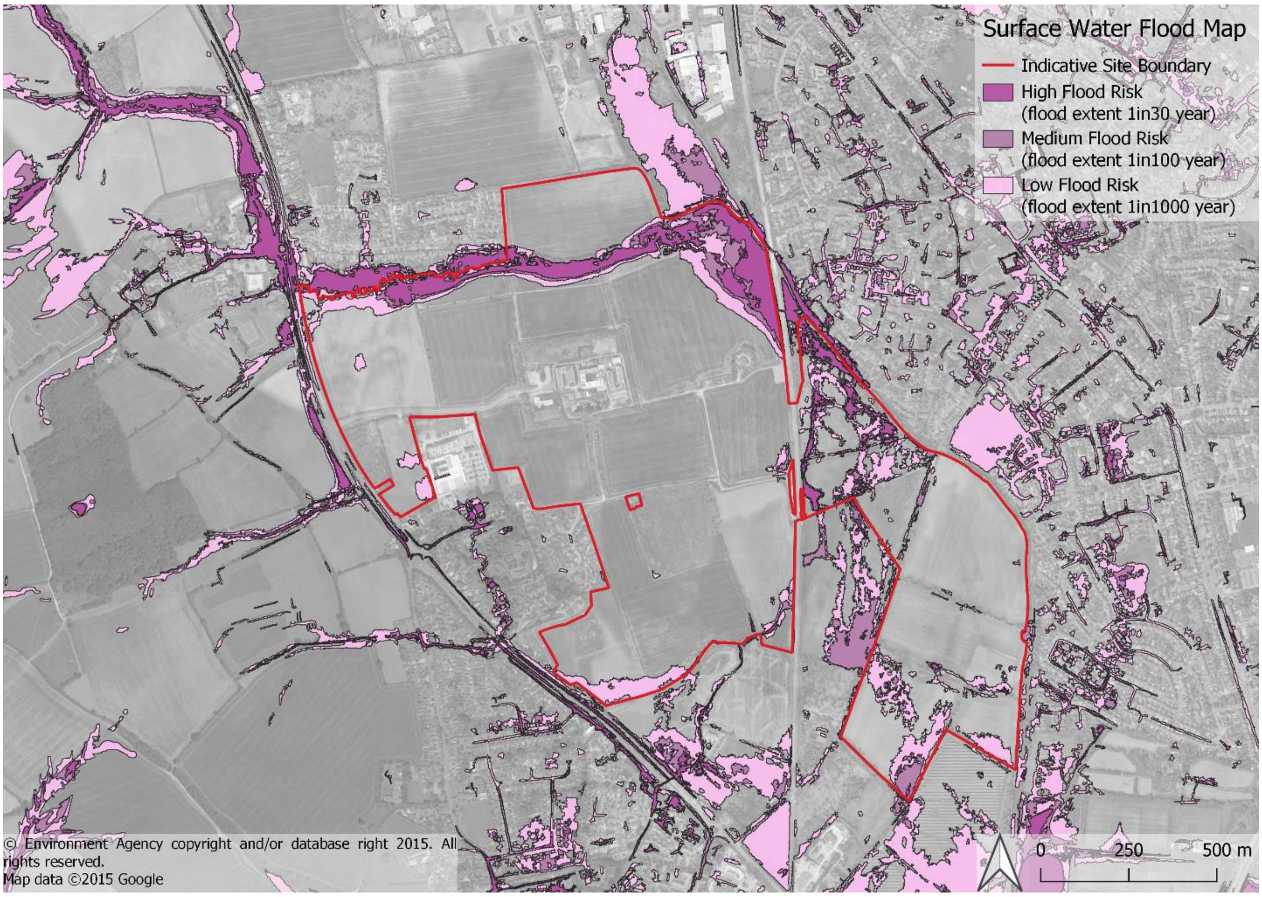

Figure 13 Surface water flood risk map

3.4.3 Flooding from Sewers

Flooding from combined sewers may occur during periods of intense rainfall when:

- The rainfall event exceeds the capacity of the sewer system;
- The system becomes blocked by debris or sediment; and,
- The system surcharges due to high water levels in receiving watercourses.

The Level 2 SFRA Addendum notes that the Thames Water (TW) DG5 register identifies 20-25 recorded incidents of sewer flooding within the post code area (OX5) covering the Site between 2006 and 2016.

The Level 2 SFRA records two flooding incidents in Kidlington in 2016 because of limited capacity.

According to Thames Water's asset plan, the existing sewer network includes five active and two abandoned Thames Water sewers which cross the site. These have been flagged for diversion, further details of these proposed diversion routes being developed in collaboration with TW can be found in the Surface Water Drainage Strategy (Appendix E).

Thames Water have confirmed that there is capacity within the sewer infrastructure for connection.

3.4.4 Groundwater Flooding

Groundwater flooding generally occurs in low-lying areas above permeable rock aquifers where the water table meets, and rises above, the ground surface.

The EA Areas Susceptible to Groundwater Flooding map (as shown in Figure 14) is a coarse data set but illustrates that the western half of The Site lies within 1 km grid squares of which between 50% and 75% of their area is considered to be susceptible to groundwater emergence. This area is classified as having a medium susceptibility to groundwater flooding. The eastern half lies within 1km grid squares of which >75% of their area is considered to be susceptible to groundwater emergence. This area is classified as being highly vulnerable to groundwater flooding. A small area north of Rowel Brook has low vulnerability to groundwater flooding (SFRA Level 2 Addendum, 2018).

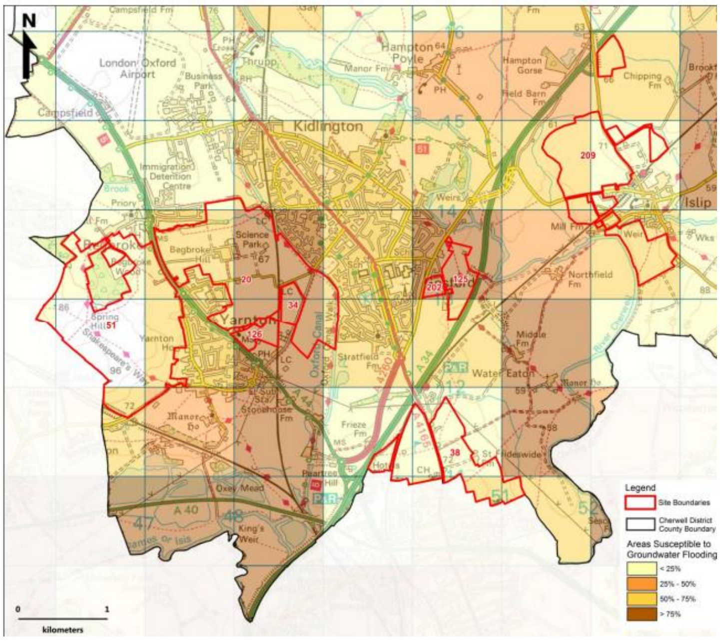

Figure 14 Areas susceptible to groundwater flooding Map (SFRA Level 2 Addendum, 2018).

A number of Ground Investigation (GI) studies have been undertaken by Hydrock to understand the geology and groundwater on the Site to inform measures which may be required as the design is developed. These include soil infiltration rate test pits, trial pits, dug pits and boreholes. The latest report which summarises the outcomes of this GI is Desk study review and GI report (Doc ref: 19114-HYD-XX-XX-RP-GE-1002).

From this information, the key points from a groundwater flooding perspective are summarised below:

- GW was encountered between 0.03m bgl and 5.83mbgl during the monitoring period which commenced in August 2022. The monitoring is being undertaken for a 12-month period.
- Based on the hydraulic gradient, within superficial deposits, the shallow groundwater flow is from the west of the site, from the topographic high, to the east and south-east, although in the north of the Site groundwater flow is locally towards Rowel Brook (from the north and the south). In the far east of the Site(in the floodplain), groundwater flows are to the south and at a shallower hydraulic gradient, but potentially influenced by the Oxford Canal which borders the east of the site. Groundwater levels and flow directions are shown in Figure 15.
- In general, groundwater was encountered within the River Terrace Deposits towards the base of the stratum with the groundwater encountered shallower in the topographic lows of the site.
- It should be noted that the ground slopes to the north-east and south and the presence of underlying relatively impermeable soils at shallow depth (Kellaways Clay Member and Oxford Clay Member) will need to be considered, as groundwater will track along the interface of these impermeable units and the overlying River Terrace Deposits.

Hydrock have confirmed that through a review of the geology encountered on the Site during the investigation works, the areas where potential springs may occur is in the north-east area of the site; north-east of Rowel Brook.

It is considered that the potential for groundwater flooding to occur is more likely to be a risk in the lower lying areas around the perimeter of the Site.

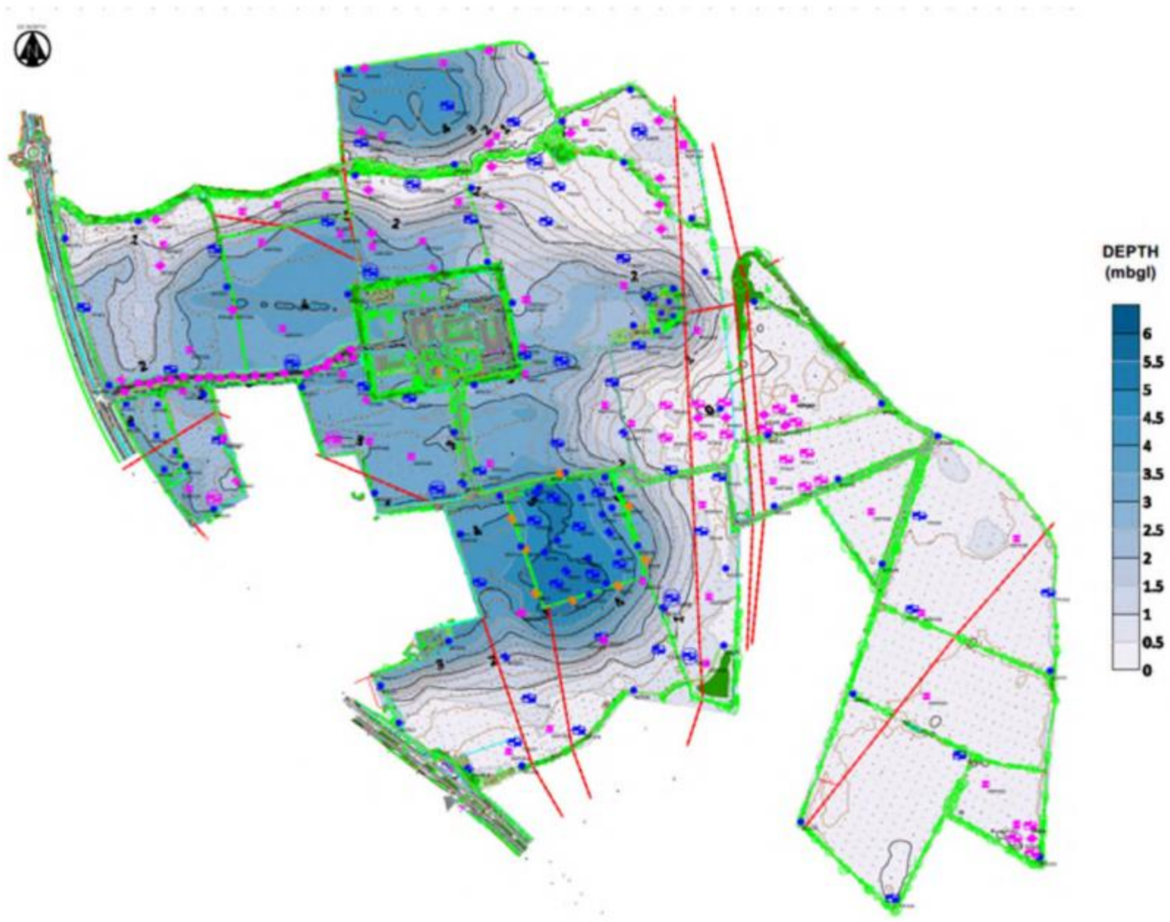

Figure 15 Groundwater depths (m bgl) (Doc ref: 19114-HYD-XX-XX-RP-GE-1002)

3.4.5 Flooding from Lakes, Reservoirs and Artificial Sources

There are several non-natural sources of flood risk including flooding from canals, reservoirs, and man-made lakes. These sources of flooding can occur when the facility is overwhelmed by high rainfall or when a dam or bank fails. Flooding from such sources can happen suddenly and can cause significant damage and danger to life. However, the likelihood of such a failure occurring is extremely low given that these are controlled water bodies.

According to the risk of flooding shown on the EA Reservoirs Map (Figure 16), a portion of the Site, mainly to the east/ south-east, is located within the maximum extent of flooding from reservoirs. This is for the scenario when there is also flooding from rivers. The Site is not at risk of reservoir flooding if the water levels within the rivers are at normal level. This flood risk is from Banbury Flood Alleviation Scheme, which is located upstream of Banbury. However, as noted above flood risk to the development from reservoirs is classed as being low.

The Oxford Canal runs through the east of the Site and is at similar ground levels to the Site. It is noted in the Level 2 SFRA Addendum that the only recorded flooding incident from the Oxford Canal in the vicinity of the Site was in January 2003 along the east side and the southernmost part of the Site due to the capacity of the canal being exceeded and overtopping. Details on the locality and extent of flooding have not been provided. However, the report identifies a residual risk of flooding to the Site from overtopping of the canal.

The water levels in the canal are controlled by a series of locks and overflow weirs which look to divert any excess flows into the river Cherwell. It is noted in the Level 1 SFRA that there is a residual risk in Cherwell of overtopping or breach failure of the Oxford Canal. There were breach failures during the 2007 summer floods, however none of these incidents were located in the vicinity of any of the Level 2 SFRA sites.

The residual risk of canal embankment failure is managed by the Canal and River Trust (CRT) who perform monthly towpath side inspections. The overall flood risk from artificial sources is Low and no further mitigation is required. It is noted that once the water overtops the canal in a more extreme event, this will have been captured in the fluvial flood modelling and therefore risk mitigated against if required for the development.

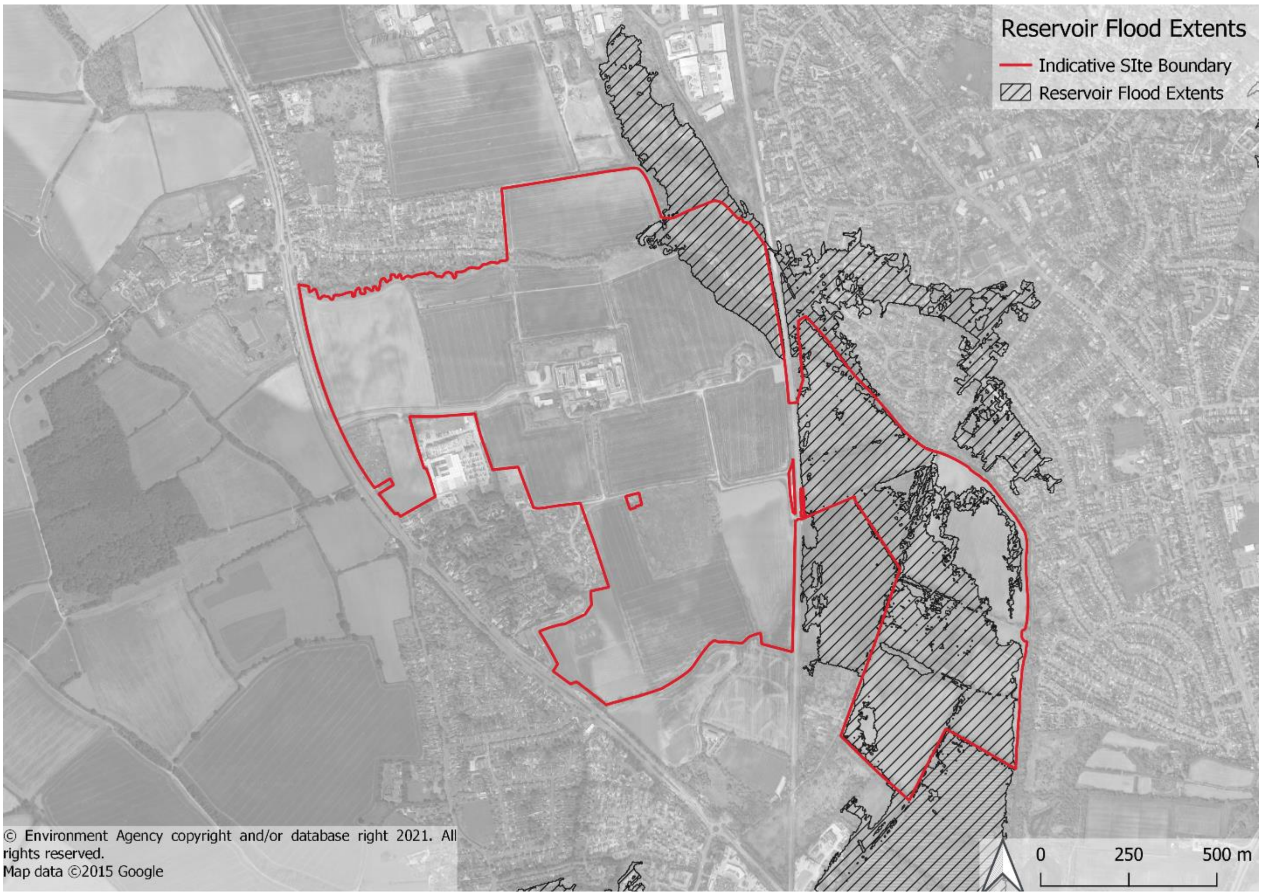

Figure 16 Reservoir flood extents map

4 Proposed Development Flood Risk

This section outlines the flood risk to the Proposed Development and any mitigation measures required to remove flood risk to the development.

4.1 Fluvial

Considering the baseline fluvial flood modelling results, as seen in Figure 17 below, the majority of Proposed Development is located outside of the key design events noted in Table 5. There are two locations where the Proposed Masterplan is within the modelled flood extents and therefore potentially at risk of flooding without further mitigation, these locations are:

- NW of the Site
    - Affecting commercial and residential assets
- South of the Site
    - Affecting the playing fields and grounds of the fields of the Secondary School

The following sections note the proposed mitigation to manage the fluvial flood risk to the development.

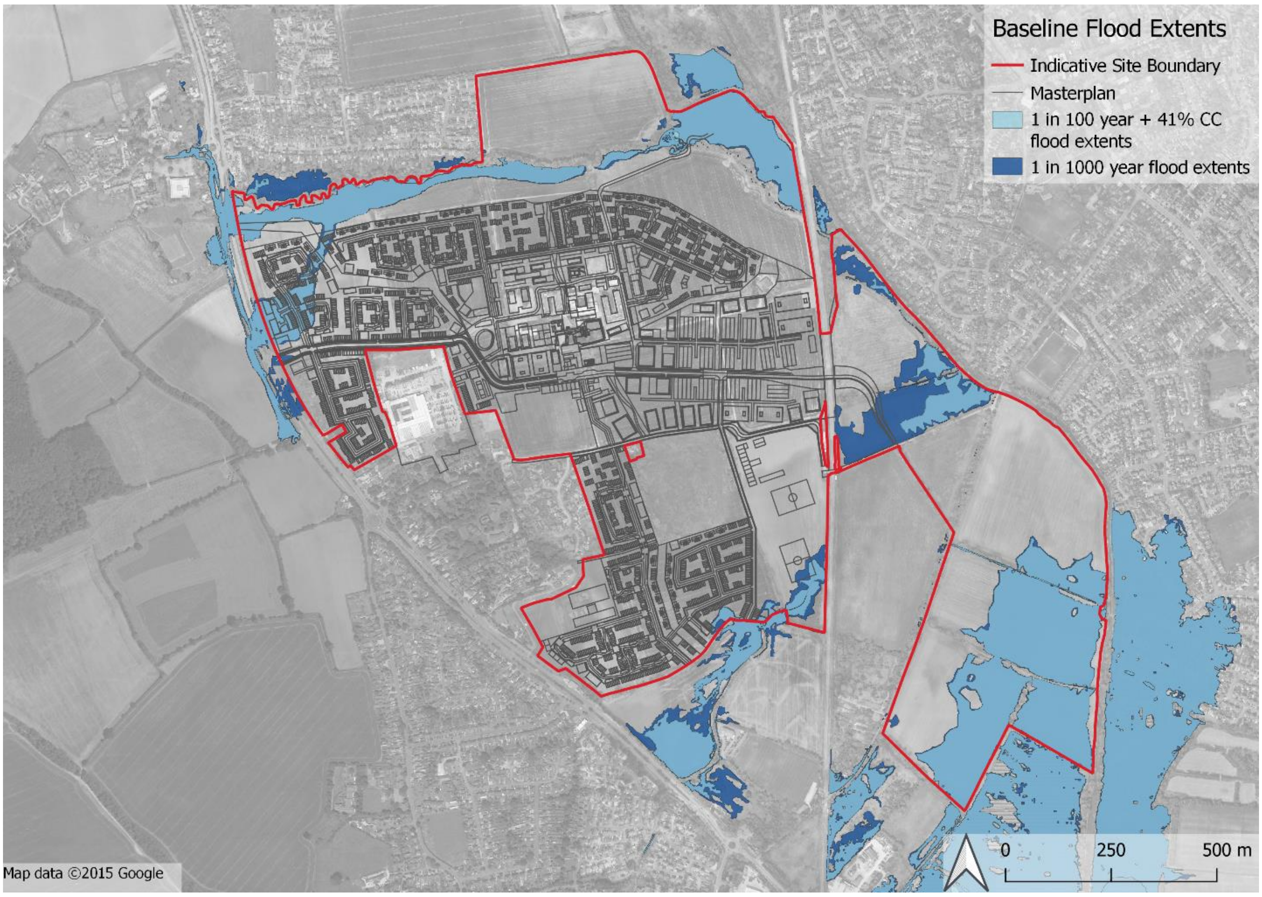

Figure 17 Baseline Fluvial Modelling Results with illustrative masterplan overlaid for the 1 in 100 year + 41% CC and the 1 in 1000 year flood extents

4.1.1 NW Area – Proposed Swale

To mitigate the flood risk to the masterplan in this location, a swale is proposed within the Site boundary along Woodstock Road which will act re-route the flood water along this designated corridor before overtopping and flowing north into Rowel Brook (concept showflon in Figure 18).

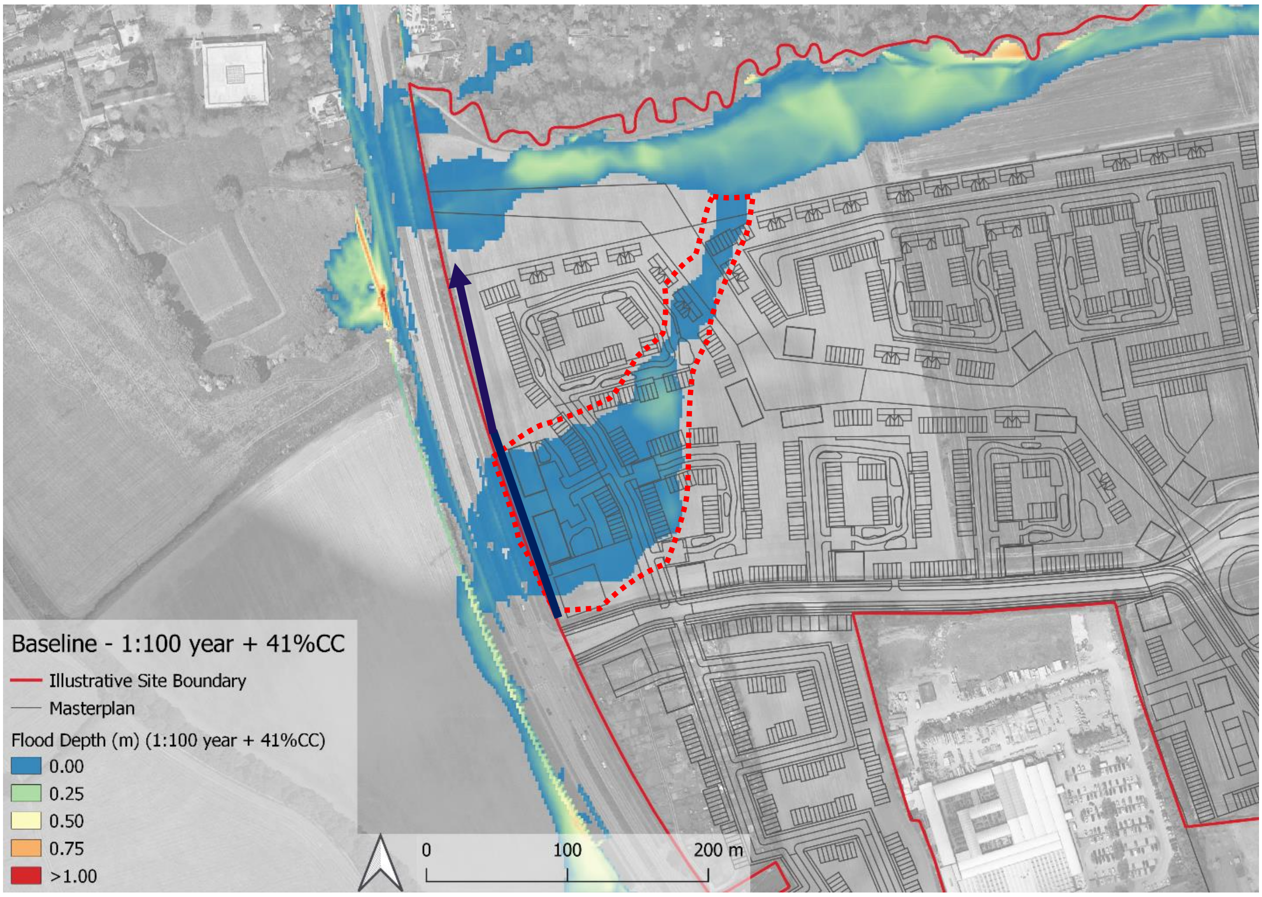

Figure 18 Concept showing proposed mitigation to remove flood risk to the illustrative masterplan in the NW area (red dashed extent shows flood extent to be removed and blue arrow shows approximate location of the swale)

The swale has been tested within an indicative scenario of the detailed hydraulic model as a 7m wide (top-of-bank), 0.5m deep channel with a 1:2 side slope, as shown in the cross illustrative section below. It has been designed to convey flows for the 1:100 year + 41% CC event with a 300mm allowance for freeboard. This design also has sufficient capacity to convey flows in the 1:1000 year event. A 300mm bund/ barrier is proposed on the bank of the swale to the east between the swale and the development. This will assist with routing the water towards the end of the ditch to the north, where it will overtop and then discharge into Rowel Brook. This area will act as a flood storage area which is an important aspect as it provides attenuation; delaying the floodwater reaching the Rowel Brook. Further detail on the modelling of this mitigation strategy is detailed within Appendix D where maximum depth and flood level differences are shown for both the 1:100 year + 41% CC event and the 1:1000 year event for an 11 hour storm duration.

Parameter Plan 01 – Development Zones includes a 10m set back from the A44 north of Begbroke Hill. This would allow for a swale of the above dimensions alongside any potential noise mitigation barrier, if required.

With this mitigation in place, water is captured and diverted around the Proposed Development layout. The flood risk associated with the overland flow route is removed for the Proposed Development in this location. This mitigation measure does not create any disbenefit along Rowel Brook, i.e. there are no increases in flood level or extent downstream of this point. This is because the proposed swale is designed in a way to capture and convey the floodwater, whilst at the same time attenuating and delaying the floodwater reaching the Rowel Brook.

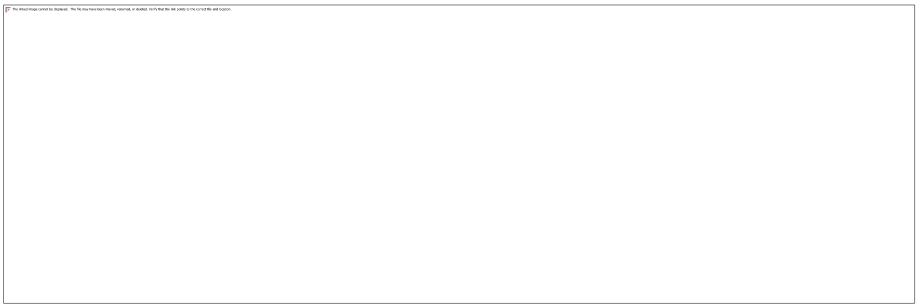

Figure 19 Illustrative cross section of proposed swale

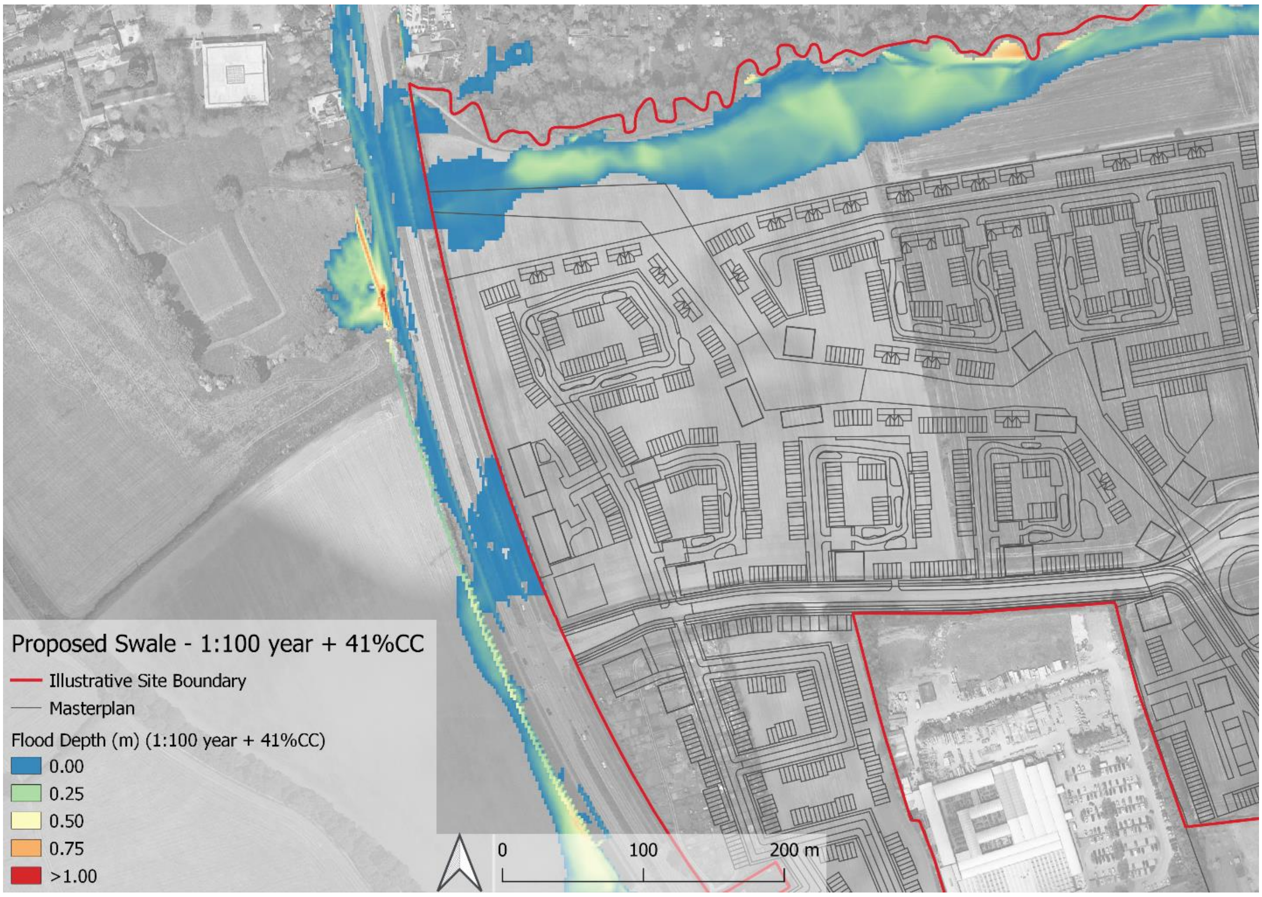

Figure 20 Modelled results showing flood extents and depths for the 1:100 year + 41% CC with the proposed swale in place.

4.1.2 Secondary School Site

Following the OCC Design Criteria for Secondary Schools outlined in Section 2.5, no part of the proposed Secondary School should be located in an area of Flood Zone 2 or 3, or have any ditches on the site. To remove any flood extents from the Secondary School Site in all events up to and including the 1:1000 year event, it is proposed to re-grade the land within the school site so that the flood risk from outside of the school site is removed.

Hydraulic modelling has been undertaken to assess the impacts associated with re-grading the school site. Mitigation measures have then been designed to manage the consequent change in flood risk on site, within the red line boundary. The purpose of the mitigation measures is to ensure that there is no increase in flood extent or flood depth outside the red line boundary and that no proposed buildings within the development are at flood risk.

The proposed land-raising across the school site would necessitate the filling-in of an existing tributary reach of the southern drainage ditch across the southwest corner of the site. So as to not limit connectivity between the ditch to the west of the school site and the southern drainage ditch, a replacement channel is proposed along the boundary of, but outside of the school site to maintain the connectivity of the southern drainage ditch. The schematisation of this proposed condition as well as the maximum depth and flood level difference plots are shown for the 1:100 year + 41%CC event and 1:1000 year event in the Technical Note in Appendix F. This shows that the school site is flood free in all events up to the 1 in 1000 year event.

The 1:100year+ 41%CC event flood extents are shown in Figure 21. Without further mitigation, it can be seen that a substantial amount of floodwater will be displaced from the school site. To offset the increase in flood volume arising from reprofiling the school site, a flood storage area has been considered within the red line boundary to the west of the school site to provide effective mitigation on a volume-for-volume basis.

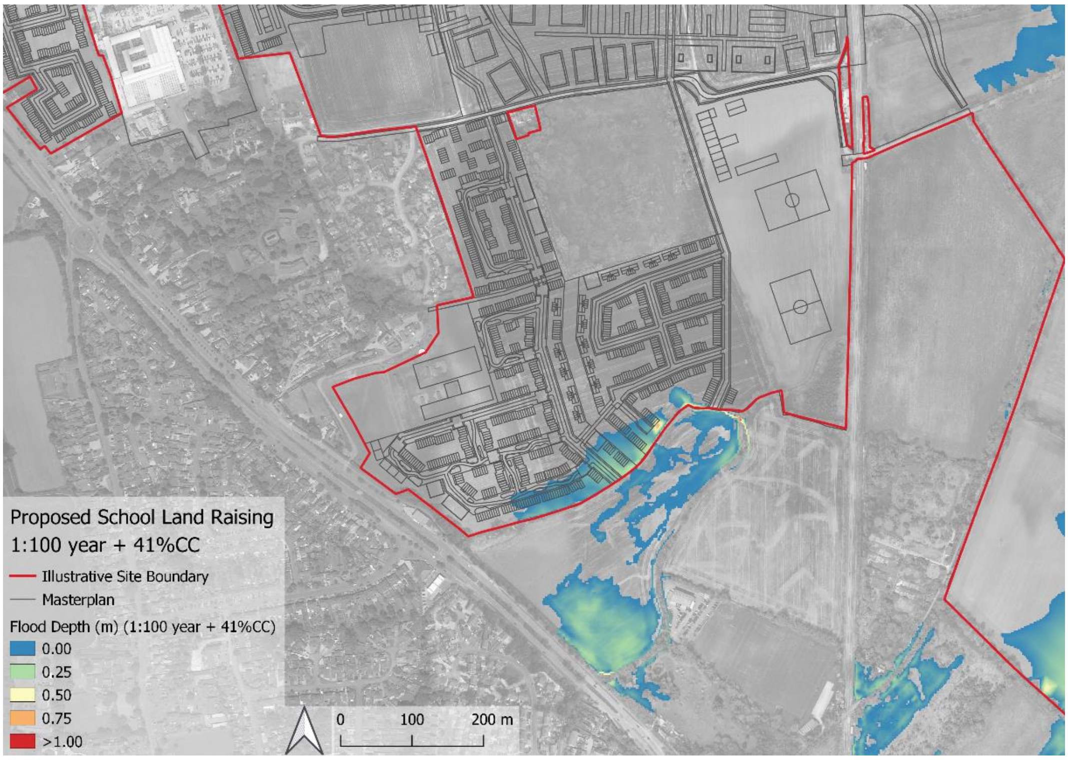

Figure 21 Flood depths shown for the 1:100 year + 41%CC event with the proposed mitigation of raising the levels in the Secondary School site implemented.

All increases in flood extents and flood depths as a result of the re-grading of the school can be accommodated within the red line boundary. It is proposed that the design of this flood storage area should store the water contributing to any observed increases in flood extent and flood depth for both the 1:100 year + 41%CC and the 1:1000 year event.

A flood storage area with plan area of 2,960m^2, with graded side slopes down to a depth of 1m, has been proposed. This can be accommodated in the area shown with the black line in Figure 22. It is proposed that in addition to the 1m depth of water, a 300mm allowance for freeboard is provided.

Review of the flood storage area shown shows that there is sufficient space to include the 300mm freeboard allowance with a 1:3 slope without any adverse impact on the adjacent building blocks.

It is recognised that the masterplan is illustrative at this stage and as part of the further development of the masterplan the area, depth and layout of this storage area will need to be developed. The proposed updates to the storage area will need to be tested through hydraulic modelling to maintain the goal of achieving no increase in flood risk off site.

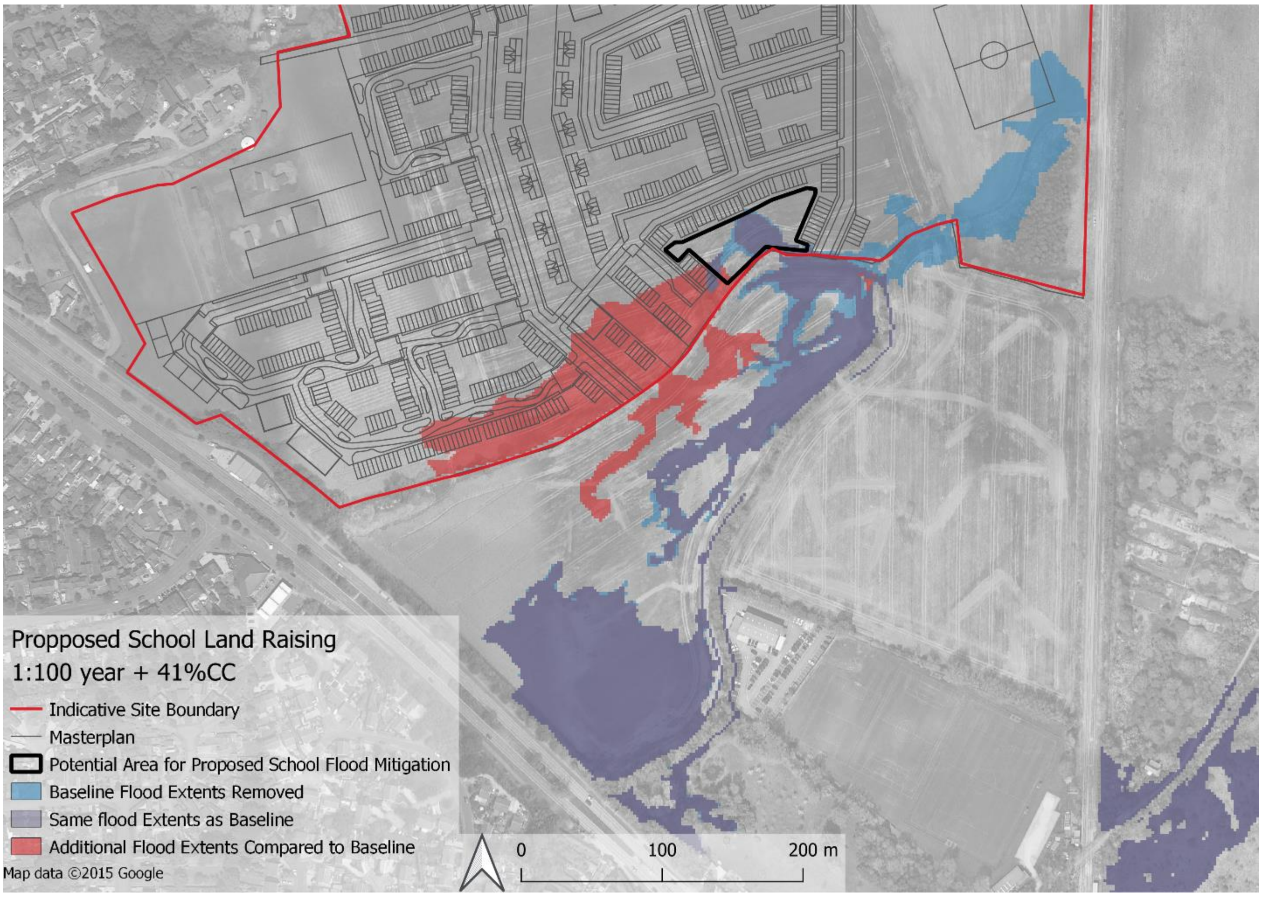

Figure 22 Potential location for flood storage area shown. This has been sized to mitigate any increase in flood extents and flood depths resulting from the proposed land raising on the Secondary School site

4.1.3 Stratfield bridge

Within the Local Plan, it is recognised that there should be a provision for a bridge crossing over the Oxford Canal to allow a connection between the Proposed Development and the land east of the canal at Stratfield Farm (allocated by Policy PR7b of the Local Plan Part 1 Partial Review).

This bridge is not being proposed as part of this outline planning application and therefore has not been considered as part of this FRA. The bridge will be brought forward in a separate planning application and a FRA will need to be undertaken to assess the impact of the proposed bridge and outline any mitigation required.

4.1.4 Finished Floor Levels

It is noted within the Level 1 SFRA that for new residential development classified as *More Vulnerable* and located within Flood Zone 2 or 3 the following guidance should be considered:

- FFL should be set a minimum of 300mm above the 1 in 100 year with an allowance for climate change.
- Sleeping accommodation should be restricted to the first floor or above.
- Less Vulnerable uses such as commercial spaces within a residential development could be below this level.

Given the above mitigation measures, no development is proposed within the Flood Zone 2 or 3 extents. However, following the principle of setting finished floor levels with appropriate resilience and to ensure that the Development is at a low risk from flooding during the 1 in 100 year + 41%, building FFLs and the access road will be set above the DFE flood level with an allowance of 300mm freeboard. These levels have been considered within the proposed earthworks levels.

4.1.5 Safe Access and Egress

During the 1:100 year + 41% CC event, access and egress via Begbroke Hill will be possible, with the A44 being clear of flooding to the South.

During the 1:1000 year event, a small depth of flood water is shown to cover the access and egress route on Begbroke Hill and along the A44 to the south. However, these depths area <100mm, therefore would not inhibit access for emergency vehicles.

4.2 Surface Water Flooding

A Surface Water Drainage Strategy has been developed for the Proposed Development (see Appendix E for full document). A summary of the key proposals are given below:

- The surface water drainage network collects rainwater at the source. Where falling within plots, these flows will be attenuated within the plot before discharge into the above and below ground surface water network at an agreed rate.
- In areas of the Site where infiltration is possible, this will allow for a reduction in flows being conveyed. It is also proposed the proposed buildings would incorporate the use of green/blue roofs and various other methods of water capture to help achieve this.
- Where falling on the roadway, it is proposed that rain water flows will be captured by permeable paving to promote infiltration prior to being conveyed by roadside swales. These roadside swales allow for a preliminary treatment and attenuation of the flows.
- Plot and roadway flows will then be conveyed to the proposed basins where, again, they will be attenuated and where possible infiltrated. Any flows up to the 1 in 100 year storm (including a 40% climate change allowance) will be discharged into the adjoining water courses at the QBAR flow rate up. This method will

ensure that the Proposed Development does not adversely impact the existing flooding conditions surrounding the site.

- The 1 in 1 year event will be held to the greenfield runoff rate. In all cases this will be done by using a Hydrobrake or other orifice control - as is required by LLFA.

- Flood Risk within the Development:
    - Surface water will be confined to the drainage system in a 1 in 30-year (+25% CC) rainfall event.
    - The proposed buildings on site will be protected from flooding in the 1 in 100-year (+40% CC) events.
    - Exceedance in the 1 in 100-year rainfall events is to be managed in exceedance routes that minimise the risks to people and property.

4.3 Environmental Permits

All temporary and permanent works within 8m of the Main Rivers requires an Environmental Permit from the Environment Agency. Both the Rowel Brook and the Southern Drainage Ditch are considered Main Rivers. As part of the drainage strategy and flood mitigation measures for the Secondary School site, works within 8m of these watercourses will be required, therefore Environmental Permits will be required. It is noted that the Environmental Permitting Regulations (EPR) process is a separate process to Planning and a Flood Risk Activity Permit (FRAP) will be applied for separate to the Planning process.

It is likely that approval will be required from the LLFA for the infilling of the ditch on the Secondary School site, which is classified as an Ordinary Watercourse. Although initial consultation with the LLFA has suggested that these works would be appropriate, it is noted that further coordination and approval should be sought prior to undertaking any modifications to Ordinary Watercourses.

4.4 Groundwater Flooding

Within the design, groundwater flood risk has been considered in the following ways:

- In designing surface water drainage attenuation areas in the low-lying areas of the site, consideration has been given to the high ground water table. In these areas, the preference is for the basins to be lined, otherwise, the design surface lifted to a sufficient level above the ground water level. The most appropriate method will be developed as the masterplan is developed further.
- Infiltration drainage is only proposed in the River Terrace Deposits in the central/ northern plateau area of the Site at topographically high areas of the site.
- If basements are proposed in higher groundwater flooding areas, they will need to be designed to be suitably watertight facilities that can withstand the hydraulic loadings, uplift from groundwater.
- The risk of groundwater springing is considered in the surface water drainage strategy, with localised grading away from developments ensuring that this surface water is directed into the surface water network. Exceedance events are to be managed in exceedance routes that minimise the risks to people and property.

The overall groundwater flood risk is considered Low with the proposed mitigation in place.

5 Summary and Conclusion

This FRA has been carried out on behalf of OUD as part of the Outline Planning Application for the proposed mixed-use development on the current site of Begbroke Science Park, Begbroke, Kidlington. The Proposed Development consists of the expansion of the existing Science Park, residential and associated amenity, education and community uses.

As advised by the EA, Baseline Hydraulic Modelling has been undertaken to produce flood mapping which provides greater detail than the EA flood maps. The majority of the Site is located within Flood Zone 1 and at low risk of flooding. Areas located in Flood Zone 2 and 3, which are at medium to high flood risk are located along the length of Rowel Brook, the parcel of land to the west of the Oxford Canal, in the North-West of the Site and around the Southern drainage ditch.

According to the NPPF, the proposed land uses include Less Vulnerable, More Vulnerable and Essential assets. All assets have been located in accordance with the sequential approach required by NPPF.

There are two locations where the Proposed Masterplan overlaps with the baseline flood extents and therefore potentially at risk of flooding without further mitigation. In the NW of the site, a swale has been proposed which captures, attenuates and diverts overland flows around the development to remove the risk to the development. On the Secondary School Site, regrading has been proposed to ensure no flooding of the school site occurs. Flood storage within the red line boundary to the west of the school site is proposed to provide effective mitigation on a volume-for-volume basis so as to ensure there are no increases in flood risk outside of the red line boundary or to any development on site.

Most of the Site is subject to Very Low surface water flood risk. There are localised areas of ponding on the Site, which are classified as having Medium to High Risk of surface water flooding. These occur around the drainage channels to the south, around the east and southeast of the Site and also on the land adjacent to the Rowel Brook.

The surface water drainage strategy for the Proposed Development will aim to replicate the predevelopment surface water runoff regime. This is achieved by capturing, filtering and harvesting (where possible) surface water as close to source as possible through source control SuDS features. The SuDS hierarchy will be used to design the Site drainage in the most sustainable way. Building upon OUD's vision for sustainable places.

All storm events up to the 1 in 100-year storm event + 40% climate change allowance are proposed to be attenuated on site and discharge from the Site to the proposed outlet at the QBAR rate. The 1 in 1-year storm event will be retained to the corresponding greenfield event. In areas of the Site where the ground conditions allow for it, infiltration is promoted to reduce the volumetric discharge of surface water from the site.

There may be a risk of groundwater flooding in the lower lying areas around the perimeter of the Site due to shallow ground water levels. This has been considered in the design of the surface water drainage strategy with regards to the location and design of attenuation ponds and use of infiltration drainage. The ground water flood risk to the Site is therefore Low.

According to the risk of flooding shown on the EA Reservoirs Map, a portion of the Site, mainly to the east/ south-east, is located within the maximum extent of flooding from reservoirs. The SFRA identifies a residual risk of flooding to the Site from overtopping of the Oxford Canal. It is noted that once the water overtops the canal in a more extreme event, this will have been captured in the fluvial flood modelling and therefore risk mitigated against if required for the development. The overall flood risk from artificial sources is Low and no further mitigation is required.

It is concluded that with the mitigation measures outlined within this FRA, the Proposed Development is at Low risk of flooding from all sources.

Appendix A National Planning Policy Framework

Planning Practice Guidance Table 1: Flood Zones

Flood Zone	Definition
Zone 1 Low Probability	Land having a less than 0.1% annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map for Planning – all land outside Zones 2, 3a and 3b)
Zone 2 Medium Probability	Land having between a 1% and 0.1% annual probability of river flooding; or land having between a 0.5% and 0.1% annual probability of sea flooding. (Land shown in light blue on the Flood Map)
Zone 3a High Probability	Land having a 1% or greater annual probability of river flooding; or Land having a 0.5% or greater annual probability of sea. (Land shown in dark blue on the Flood Map)
Zone 3b The Functional Floodplain	This zone comprises land where water from rivers or the sea has to flow or be stored in times of flood. The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. Functional floodplain will normally comprise: • land having a 3.3% or greater annual probability of flooding, with any existing flood risk management infrastructure operating effectively; or • land that is designed to flood (such as a flood attenuation scheme), even if it would only flood in more extreme events (such as 0.1% annual probability of flooding). Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map)

Note: The Flood Zones shown on the Environment Agency's Flood Map for Planning (Rivers and Sea) do not take account of the possible impacts of climate change and consequent changes in the future probability of flooding. Reference should therefore also be made to the Strategic Flood Risk Assessment when considering location and potential future flood risks to developments and land uses.

Paragraph: 078 Reference ID: 7-078-20220825

Revision date: 25 08 2022

Planning Practice Guidance Table 2: Flood risk vulnerability and flood zone 'incompatibility'

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

Key:

✓ Exception test is not required

X Development should not be permitted

Notes to table 2:

- This table does not show the application of the Sequential Test which should be applied first to guide development to the lowest flood risk areas; nor does it reflect the need to avoid flood risk from sources other than rivers and the sea;
- The Sequential and Exception Tests do not need to be applied to those developments set out in National Planning Policy Framework footnote 56. The Sequential and Exception Tests should be applied to 'major' and 'non major' development;
- Some developments may contain different elements of vulnerability and the highest vulnerability category should be used, unless the development is considered in its component parts.

“†” In Flood Zone 3a essential infrastructure should be designed and constructed to remain operational and safe in times of flood.

“*” In Flood Zone 3b (functional floodplain) essential infrastructure that has passed the Exception Test, and water-compatible uses, should be designed and constructed to:

- remain operational and safe for users in times of flood;
- result in no net loss of floodplain storage;
- not impede water flows and not increase flood risk elsewhere.

Paragraph: 079 Reference ID: 7-079-20220825

Revision date: 25 08 2022

Planning Practice Guidance Annex 3: Flood Risk Vulnerability Classification

Essential infrastructure

- Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk.
- Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including infrastructure for electricity supply including generation, storage and distribution systems; including electricity generating power stations, grid and primary substations storage; and water treatment works that need to remain operational in times of flood.
- Wind turbines.
- Solar farms.

Highly vulnerable

- Police and ambulance stations; fire stations and command centres; telecommunications installations required to be operational during flooding.
- Emergency dispersal points.
- Basement dwellings.
- Caravans, mobile homes and park homes intended for permanent residential use.
- Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure'.)

More vulnerable

- Hospitals
- Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels.
- Buildings used for dwelling houses, student halls of residence, drinking establishments, nightclubs and hotels.
- Non–residential uses for health services, nurseries and educational establishments.
- Landfill* and sites used for waste management facilities for hazardous waste.
- Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.

Less vulnerable

- Police, ambulance and fire stations which are not required to be operational during flooding.
- Buildings used for shops; financial, professional and other services; restaurants, cafes and hot food takeaways; offices; general industry, storage and distribution; non-residential institutions not included in the 'more vulnerable' class; and assembly and leisure.
- Land and buildings used for agriculture and forestry.
- Waste treatment (except landfill* and hazardous waste facilities).
- Minerals working and processing (except for sand and gravel working).
- Water treatment works which do not need to remain operational during times of flood.
- Sewage treatment works, if adequate measures to control pollution and manage sewage during flooding events are in place.
- Car parks.

Water-compatible development

- Flood control infrastructure.
- Water transmission infrastructure and pumping stations.
- Sewage transmission infrastructure and pumping stations.
- Sand and gravel working.
- Docks, marinas and wharves.
- Navigation facilities.

- Ministry of Defence installations.
- Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location.
- Water-based recreation (excluding sleeping accommodation).
- Lifeguard and coastguard stations.
- Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms.
- Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

*Landfill is as defined in Schedule 10 of the Environmental Permitting (England and Wales) Regulations 2010.

Appendix B Hydraulic Modelling Strategy Technical Note

NOVEMBER 30, 2022

Hydraulic Modelling Strategy

Begbroke Innovation District

Prepared for:

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EdenvaleYoung

Report Title Hydraulic Modelling Strategy

Project Name Begbroke Innovation District

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Report Revision C

Client Buro Happold

Written by	Dr. Gerald C J Morgan	November 30th 2022
Checked by	Dr. Gerald C J Morgan	November 30th 2022
Approved by	Dr. Gerald C J Morgan	November 30th 2022

Revision	Issued to	Date
A	Buro Happold	November 4th 2022
B	Buro Happold	November 21st 2022
C	Buro Happold	November 30, 2022

EdenvaleYoung

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SCOPE

1. Introduction

AEP	Epoch	Estimate	Uplift
3.33%	Present		0%
1%	Present		0%
1%	2080s	Central	26%
1%	2080s	Higher	41%
0.1%	Present		0%

Table 1.1: Fluvial events to be simulated

1.1 Project Requirements

Edenvale Young Associates and Buro Happold have been commissioned to undertake hydrological analysis and baseline flood risk modelling of the Begbroke Innovation District site in North Oxford, between Begbroke, Yarnton and Kidlington. The site boundary is shown in figure 1.1.

The purpose of the study is to define the flood extents and map the flood depths and hazards associated with a set of key design events required for the planning process, specifically the 3.33%, 1% and 0.1% AEP present day events and the 1% AEP events with climate change allowances to the 2080s. These events are shown in table 1.1.

1.2 Purpose of this Note

This technical note outlines the proposed approaches to the hydraulic modelling and hydrological analyses in order to gain agreement to these methodologies at the earliest possible stage. This approach was discussed with the Environment Agency (EA) in a meeting of 16th November 2022. It was anticipated in this meeting that the EA would be able to review and comment on the technical detail of this note by late December, unless substantial flood events occurred which might result in a delay.

This note will therefore present the approaches that Edenvale Young Associates and Buro Happold propose to use to meet the above requirements. At each stage, the key assumptions behind each decision will be highlighted and justification will be provided, detailing why the results of the work is not believed to be affected by those assumptions or the actions that will be taken to minimise the impact of each assumption.

Due to the project programme, we are due to commence the hydrological analysis and hydraulic modelling works ahead of receiving the EA's comments on this note. We would appreciate the EA's feedback at your earliest convenience to reduce the risk of abortive work.

1.3 Basic Approach

The flood risk will be assessed through the construction of a baseline hydraulic model using industry-standard software in combination with a hydrological analysis.

Hydraulic modelling of the site has been requested from the Environment Agency and there is no existing model of the site. Current flood mapping is understood to have been derived from JFLOW modelling and therefore is not considered appropriate for a site specific Flood Risk Assessment. Accordingly, as part of this work, it will be necessary to undertake detailed hydrographic survey of the watercourses and build a new hydrological and hydraulic model from scratch.

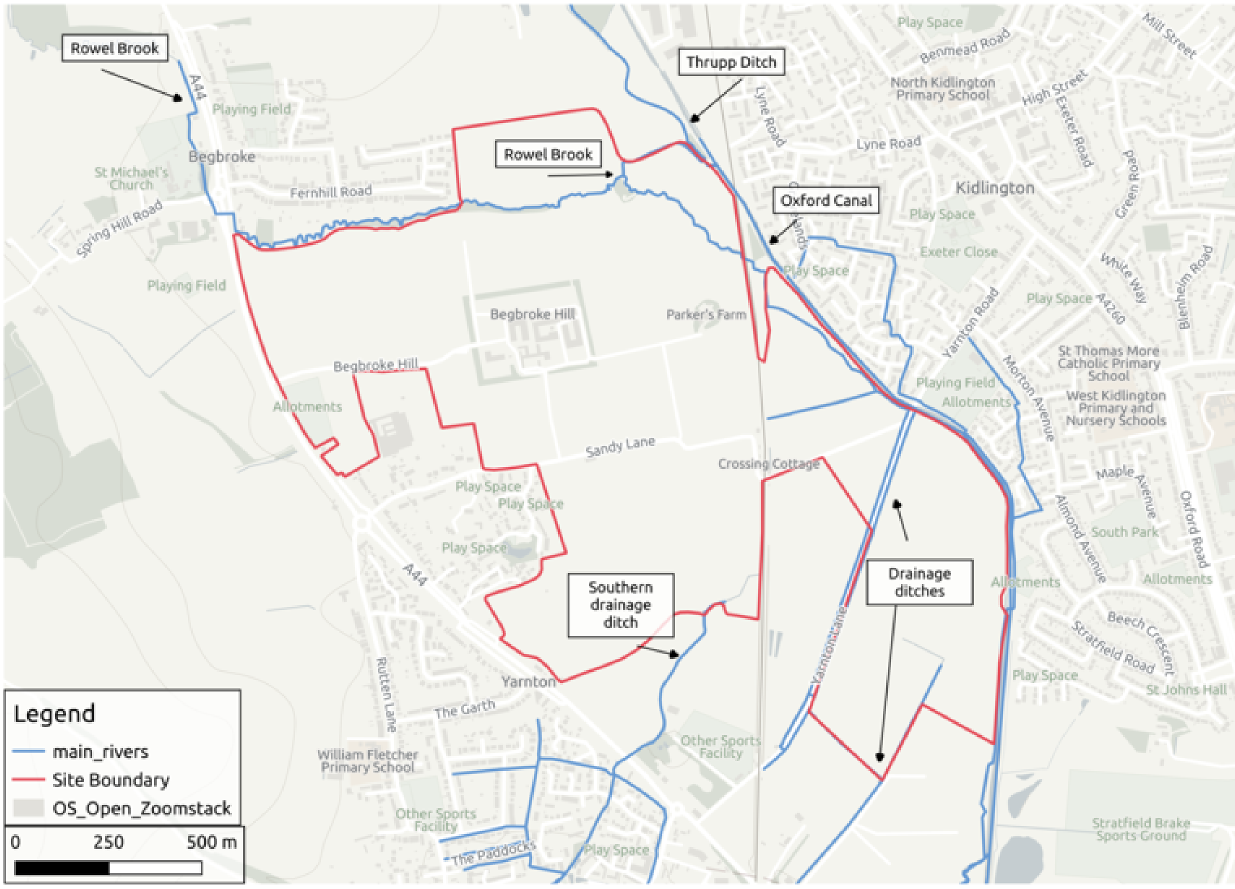

Figure 1.1: Red-line boundary of the site of interest

The hydrological analysis will be undertaken using the FEH methods as updated through the EA's technical guidance (LIT11832) along with the current latest versions of the WINFAP and ReFH2 software. The hydraulic modelling will be undertaken with the latest version of the widely-used TUFLOW software.

1.4 Site Overview

This section of the report provides a brief description of the significant watercourses and flow routes based on an initial desk study of the site and a site visit conducted on 12th October 2022.

There are a number of watercourses on site including the Rowel Brook, the Oxford canal, the Thrupp ditch, the southern drainage ditch and some other field ditches, shown in figure 1.1.

The Rowel Brook originates west of Oxford Airport and drains east to the A44 before turning south towards Begbroke. Once at Begbroke the Rowel Brook is culverted under the road and flows east across the northern boundary and, after bifurcating, through the north western corner of the proposed development site. This watercourse appears to be ephemeral, having no flow or standing water at the time of the site visit.

The watercourse bifurcates in a small wooded area to the north of the proposed development. On the site visit the ground levels in this wooded area appeared quite confused and there was no obvious low-flow connection to the south eastern branch of the bifurcation. A number of ponds in this location did contain water behind a weir that would discharge into the south eastern branch, but there was no obvious connection from these ponds that indicated that they took water from the Rowel Brook. It is anticipated that the proposed detailed survey will resolve the surface water connections in this location.

The north eastern branch from the bifurcation flows north and then east and appears to discharge into the Oxford Canal shortly after its tributary with the Thrupp Ditch. This branch contained standing water during the site visit.

Assumption 1. *Standing water in the Rowel Brook (NE) is maintained by the backwater from the canal.*

It is anticipated that the standing water observed in the Rowel Brook during the site visit is at a constant level matching the pound level of the Oxford Canal. This should be confirmed by the detailed survey. There is a small risk that this is not the case and that this water originates from another source, potentially groundwater, that would have to be identified and modelled.

The south eastern branch of the Rowel Brook flows through the site and, after passing through a culvert under the railway line, along the eastern edge of the site. After crossing under Sandy Lane it flows in a pair of ditches along either side of Yarnton Lane before being routed through field drainage and crossing back under the A44 south of the site. This branch was largely dry during the site visit. The ditches along Yarnton Lane appeared poorly maintained and the connectivity between the ditches was not always clear.

Assumption 2. *There exists an uninterrupted flow route along the Rowel Brook (SE).*

It is assumed from the site visit, the designation of main rivers, and the existing mapping of the watercourses that the ditches along Yarnton Lane are

A. connected to the Rowel Brook at their upstream extent,
B. continuous along both sides of Yarnton Lane,
C. connected to each other at their southern end as shown in the watercourse map,
D. connected to the return crossing under the A44 via field drains,
E. are not connected to allow discharge into the Oxford Canal.

It is anticipated that these assumptions will be confirmed by detailed survey.

The Thrupp ditch drains a catchment north of the site and flows south through an industrial estate, east of Bristol Airport. It runs just west of the Oxford Canal, flowing south, before entering a culvert under a footpath and joins with the Rowel Brook and Oxford Canal on the north eastern boundary of the site.

The Oxford Canal runs in a southerly direction from the northeast of the site, down the eastern edge of the site boundary. There are two pounds that affect the site. The most significant runs from a lock just upstream of the confluence with the Rowel Brook and Thrupp

Ditch along the eastern boundary of the site to a lock near Stratfield Road, Kidlington. The second pound starts here and runs south for a considerable distance, ending a short way upstream of the A40. The lock between these two pounds has a substantial side-spill weir upstream of it to maintain the upper pound level. This discharges into a parallel channel around the lock on the western side and returns to the canal downstream.

The Southern drainage ditch originates to the west of the railway within the site boundary and flows southwest through Yarnton.

Assumption 3. *Field Drainage on site is not fluvially significant*

Except where noted in this section, it is assumed that field drains on the site are not significant for the purposes of delineating fluvial flood risk. The site visit showed that most of the field drains that are not associated with the ditch system along Yarnton Lane (discussed elsewhere) seem to have limited connectivity to the fluvial network. All of the field drains currently designated as main river will be included in the model, regardless of this assumption.

2. General Methods

2.1 Hydrological Analysis

Base catchment

There is no flow or level data available for the catchment of interest, with no known existing studies to review. As such, a standard FEH analysis will be undertaken which will consist of both the Statistical and ReFH methods in order to establish the worst case scenario which will then be applied to the hydraulic model. We believe this will provide a conservative estimate of flood risk for the site.

The site is almost entirely covered by the catchment delineated from the FEH web service shown in figure 2.1 and catchment descriptors and peak flow estimates will be derived for this base catchment.

This catchment is not believed to be well-defined, and it is not reasonable to use this catchment's peak flow estimates directly. In particular, this catchment does not follow the expected flow route for the Rowel Brook to the south west where it is believed to return under the A44 and it ignores a number of significant man-made barriers to flow that constrain this area from functioning as a single hydrological catchment.

Catchment delineation

In order to gain a better understanding of the surface flow routing in this area a broad-scale, 2D-only model will be constructed of the catchment shown in figure 2.1 and a first approximation of the 0.1% AEP design event rainfall will be applied directly to the grid. The results of this Direct Rainfall Model (DRM) will allow

1. the key off-site sub-catchments affecting fluvial flood risk to

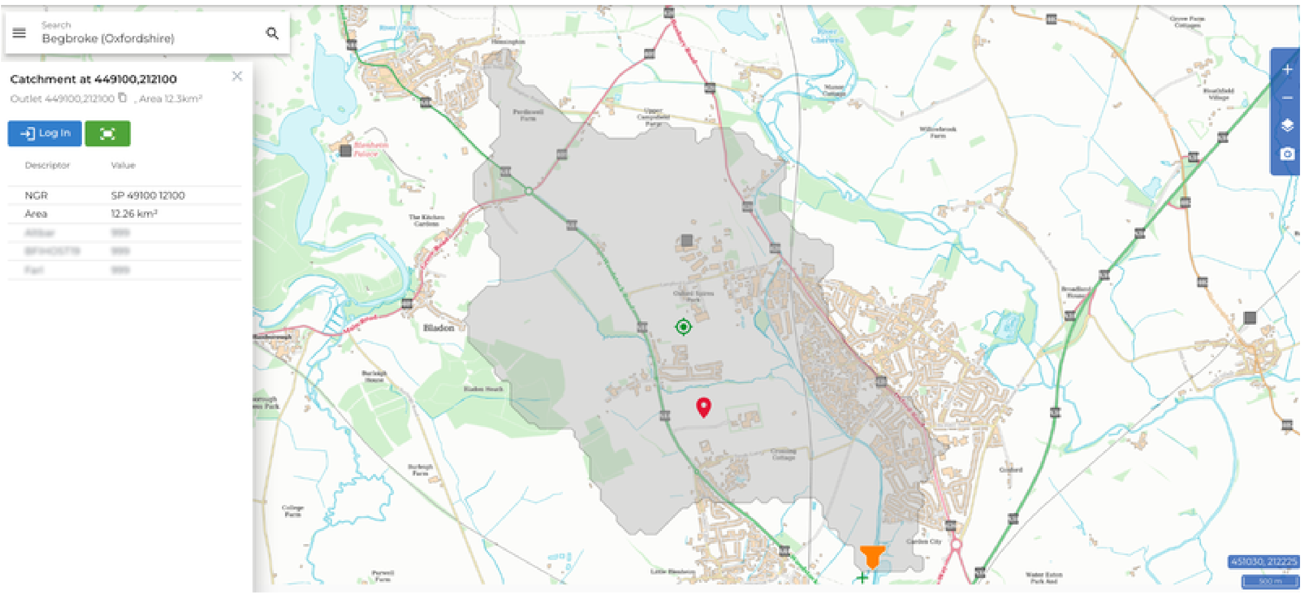

Figure 2.1: Base catchment from the FEH web service

the site to be delineated, and

2. the on-site sub-catchments to be delineated and the flow routes by which these on-site sub-catchments drain to the watercourses to be identified.

It is expected that several adjustments will be made to the base catchment in the light of the results from the DRM. In particular, it is expected that the Oxford Canal will form a hydrological barrier and that the urban area of Kidlington, to the east of the site, will be removed from the base catchment. Conversely, the base catchment on the FEH web service does not include the fields north east of Yarnton, through which it is anticipated the bulk of the site drains and these will need to be added. The base mapping in figure 2.1 also shows several watercourses crossing the supposed catchment boundary, particularly along the western extent, indicating that the catchment is not well delineated in this area.

Assumption 4. *The Oxford Canal is a hydrological barrier.*

The Oxford Canal marks the eastern boundary of the site and it is assumed that the canal forms a barrier to flow, with rain falling east of the canal, in Kidlington, draining south, parallel to the canal, and rain falling west of the canal falling within the Rowel Brook catchment.
This assumption is largely supported by:

- existing surface water and flood risk mapping,
- on-site observations during the site visit that did not reveal any formal discharges into the canal from the left (eastern) bank,
- communication with the Canal & Rivers Trust who have indicated that they have no record of any current outfalls or discharge points between the two locks.

The watercourse map (figure 1.1) does show two watercourses discharging into the canal on the eastern bank, but it was not possible to locate these discharge points or (with the exception of a small reach on the playing field at Kidlington Football Club) watercourses during the site visit. It is therefore expected that normal flows from the urban area of Kidlington drain southwards to the ponds east of the solar farm.

It is possible that urban run-off from Kidlington could enter the canal during very extreme events. The likelihood of this and potential catchment area will be assessed using the DRM and a sensitivity analysis will be undertaken to determine if urban run-off from Kidlington discharging into the canal will significantly affect water levels in the canal and hence water levels on site.

Hydrological Schematisation

The final model is expected to include at least two major inflows representing the off-site catchments of the Rowel Brook and the Thrupp Ditch which will be introduced as point inflows at the model boundary. The expected locations of these inflows are shown in figure 2.2. It is anticipated that catchments for these major inflows will be defined and that individual statistical peak flow analyses will

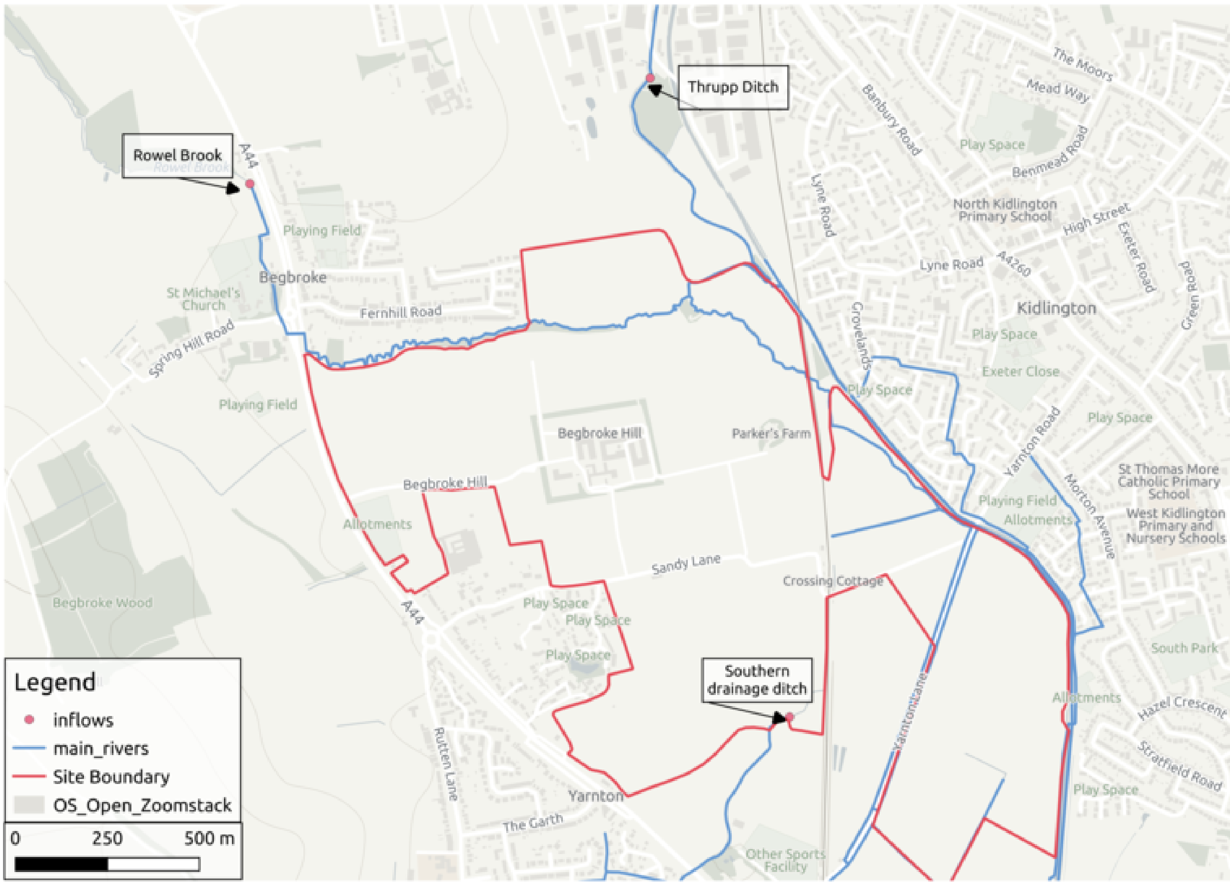

Figure 2.2: Inflow locations

be undertaken for each of these off-site catchments. ReFH2 models will be derived that match these statistical peak flow estimates at their critical storm durations.

The model will also have a number (to be determined) of delineated on-site sub-catchments whose inflows will be introduced in or near the watercourses. It is anticipated that some of these catchments may extend off-site to some limited degree, particularly to capture the areas north of the Rowel Brook, between the two major inflows, and any potential overland flow route approaching the site from the direction of Begbroke Wood, to the west. Catchment descriptors for the newly-derived sub-catchments will be calculated using standard transformations of the descriptors from the overall FEH catchment shown in figure 2.1 and ReFH2 models will be derived for each of these sub-catchments. The distribution of the inflows from the on-site sub-catchments will be informed by the results of the DRM.

Where it is unclear from the DRM whether a catchment would discharge to a watercourse or simply form standing water, that water will be distributed evenly along the watercourse for the purpose of this modelling.

Assumption 5. *All water reaches one of the modelled watercourses.*

For the purposes of flood risk modelling it is assumed that all rainfall and water falling on the site and the catchments upstream will reach one of the modelled watercourses. It is assumed that any rainfall that would form standing surface water not connected to a watercourse will be handled by the surface water drainage scheme and the over-land flow routes associated with this will not be modelled here.
This approach should yield a flood risk map that may, conservatively, include some areas that could be considered surface water flooding, but which is much less likely to erroneously exclude areas of fluvial flood risk.

The on-site catchment feeding the southern drainage ditch will be included as a point inflow at the upstream end of that ditch as shown in figure 2.2. This approach is in line with common flood risk modelling practice and is a conservative representation of the flood risk along this reach.

Design Storm Duration

The design critical storm duration is likely to be longer than the individual critical storm durations of any of the sub-catchments. Accordingly the ReFH2 design critical storm duration and resulting rainfall hyetograph of the base catchment will be applied to all of the sub-catchments to derive design events. It should be noted that the ReFH2 models for each of the sub-catchments for which statistical peak flow estimates are available will have been adjusted to be able to reproduce the statistical peak flows for that sub-catchment's critical storm duration.

Assumption 6. *Single Design Storm*

In line with the FEH methods, a single design storm will be assumed over the modelled catchment. This storm's rainfall totals for each design AEP will be derived using the FEH13 "DDF2" model applied to the base catchment that covers the majority of the site. A rainfall hyetograph will be derived for this storm using the normal approaches in ReFH2 and this single hyetograph will be applied to each sub-catchment for the design events. For climate change events each sub-catchment's inflow hydrograph will be adjusted individually. Events with an additional storm duration will be run to identify any potential for increased flood risk from the southern drainage ditch in a short-duration event.

2.2 Hydraulic Modelling Approach

Software and Solver

The hydraulic model will be constructed using the latest version of ESTRY-TUFLOW with HPC (currently TUFLOW build 2020-10-AE). The TUFLOW software package has been used extensively in the UK for over 15 years and is a successfully benchmarked and trusted modelling package. ESTRY has been selected due to the meandering, shallow gradient and ephemeral nature of the Rowel Brook and the known limitations with the FMP software for modelling rivers with these characteristics.

The TUFLOW QuadTree solver will be used in order to get high resolution in several critical areas of the model where it is unclear

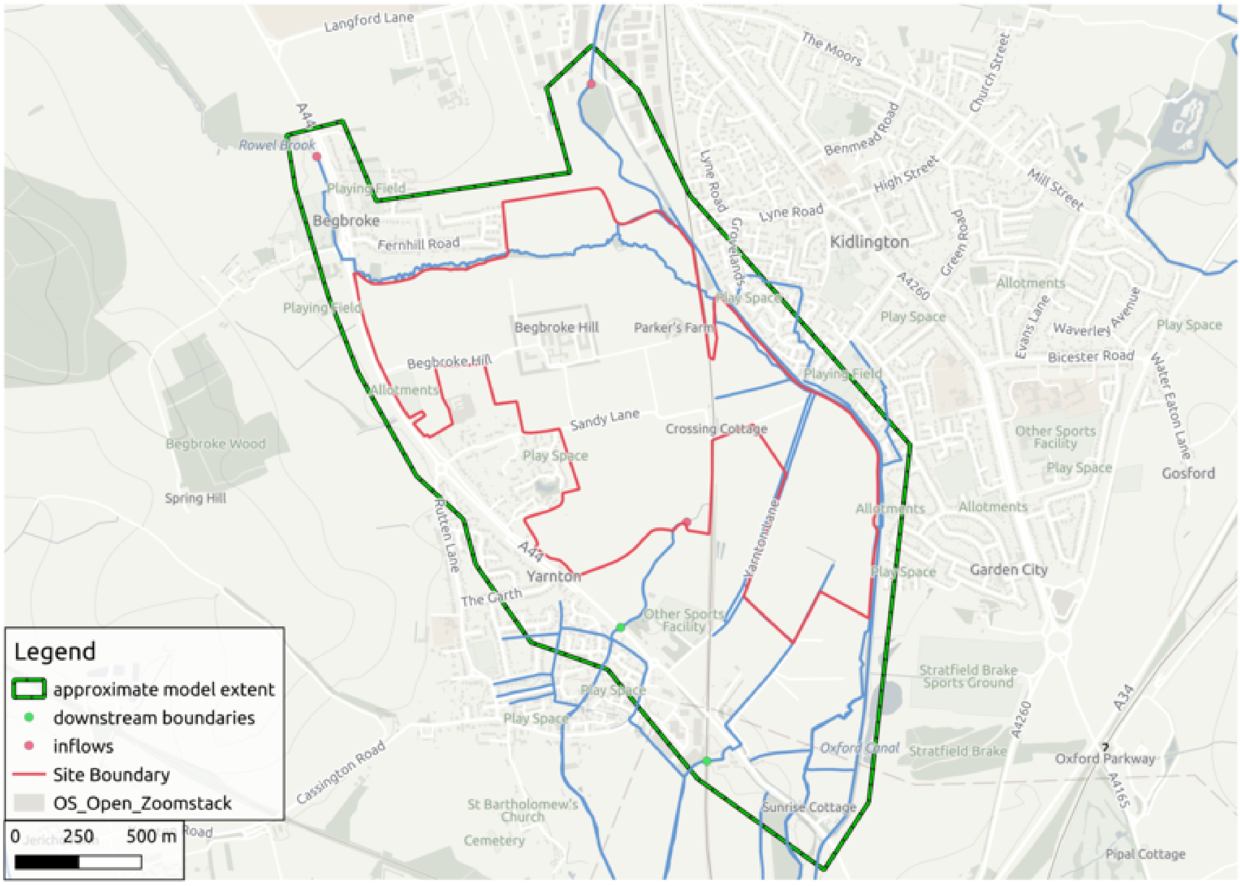

Figure 2.3: Extent of hydraulic modelling.

how flow will split between several different flow routes. The base grid size of the model will be informed by the LiDAR available at the site and the level of detail required. It is anticipated that a 4m base grid will be used with the QuadTree approach used to drop the cell size to between 0.5-1m in critical locations.

Model Extent

The approximate plan extent of the hydraulic modelling that is currently proposed is shown in figure 2.3. This proposed extent fully covers the site of interest and extends upstream on the Rowel Brook and its tributaries as well as downstream as far as is practical.

Representation of Channels

The mid-point approach for ESTRY cross section representation will be used for open channel and end-to-end representation for structures. This approach reduces the amount of interpolation of data performed by the ESTRY solver and provides a representation of the channels that is closer to the surveyed data. This approach allows a high detail model to be achieved through the use of a river centre-line that allows the modelled bed level to vary significantly between cross-sections. This centre-line, surveyed at a 2m spacing along each channel (coarser along the Oxford Canal), will allow critical high and low points in each channel to be identified and included in the modelling even where full cross-sections are not available at those locations.

Sensitivity Analysis

Sensitivity analyses will be run on the modelling. Two additional simulations will be run for the 1% AEP present epoch (no climate change allowance) event that increase and decrease the roughness of the channel and land surfaces by 20%. The effect of these changes on flood depths and extents will be mapped. This analysis will inform whether the results of the model are sensitive to the roughness values selected.

Assumption 7. *Hydraulic model results are not sensitive to roughness.*

The selection of Manning's "n" roughness parameters for hydraulic models is a significant source of uncertainty, particularly for out-of-bank areas and complex channels. The parameter values selected for this model will be based on Edenvale Young's standard TUFLOW modelling template, giving consistency with a large number of existing models in the UK, many of them well-calibrated to observed data. In order to quantify the impact of this uncertainty on the results of the modelling a sensitivity analysis will be performed on the selection of these parameters.

A sensitivity analysis run will be undertaken on the downstream boundary conditions on the Rowel Brook and southern drainage ditch to quantify the extent to which assumptions made at these locations affect flood risk on-site. This sensitivity analysis may be combined with the proposed sensitivity analysis to increased inflows to the Oxford Canal from Kidlington discussed above.

Assumption 8. *Hydraulic model results are not sensitive to the downstream boundary location.*

The downstream boundaries of the modelling have been located as far downstream of the site as is reasonably practical, but there remains a risk that changes to the assumptions made about the water level or flow conditions downstream of the model would change the results of the modelling on-site. Where possible the boundaries have been located at hydraulic structures which would be expected to mitigate the effects of changes to the downstream conditions propagating back to the site, but a sensitivity analysis will be performed to quantify the impact of the assumptions made about these downstream flow conditions.

SCOPE

3. Specific Considerations

3.1 Rowel Brook, NW

The upstream extent on the Rowel Brook will be taken at or upstream of an existing in-line flood attenuation feature in Begbroke, shown in figure 3.1. The exact location will be determined by the availability of survey of the Brook to the west of the A44. This feature is expected to provide a flow control upstream of the site and will be directly included in the hydraulic model. The model will allow for the potential for this flood attenuation feature to fill and overtop the A44 and reach the site through Begbroke and will directly model the culverts under the A44 at the north western corner of the site.

The 2D modelling will extend north of the Rowel Brook and site red line sufficiently to include the most extreme flood extents within the 2D model. This will necessarily include properties along the Fernhill Road in Begbroke, as well as the properties around the roundabout on the A44, Woodstock Road. The area is shown in figure 3.1.

The Rowel Brook meanders along the northern boundary of the site and south of Fernhill Road will be represented using mannings "n" roughness values, as opposed to using form losses for every bend, and a sensitivity will be undertaken on the roughness value selected to ensure that this does not unduly influence the results at the site of interest. Where hydraulic structures along this reach are thought to directly impact the flow these will be modelled. At a minimum the river crossing at the eastern end of Fernhill Road will be modelled. In general, ad-hoc footbridges and garden features that do not present a significant cross sectional obstruction to the flow will not be explicitly included in the model.

Assumption 9. *The Rowel Brook catchment does not have significant attenuation upstream of Begbroke.*

The Rowel Brook catchment upstream of the attenuation pond in Begbroke will be represented as a single point inflow with a ReFH2-derived hydrograph. This assumes that the whole of this catchment does drain through this location and there is no route for water from the catchment to bypass this structure and reach the site directly, even at high return periods.
The DRM should identify if there is a significant risk of flows from the Rowel Brook upstream of the attenuation structure overtopping the A44 into Begbroke and hence potentially into the site. If this eventuality is identified the effect will either be directly modelled or a flow split will be determined, depending on the availability of off-site survey of the Rowel Brook west of the A44.

The inflows from the on-site sub-catchments along this reach will be distributed based on the results of the DRM. There is a possibility that some of the catchment draining to this reach drains from the western side of the A44 or from the area north of the site, between the two main inflow catchments. It is not currently clear what proportion of the land west of the A44 will drain to the Rowel Brook and what connectivity exists beneath the A44 to enable this. The DRM will be used to identify whether this part of the catchment should drain to the Rowel Brook where it crosses under the road in Begbroke or whether some proportion should be modelled overtopping the A44 on to the site.

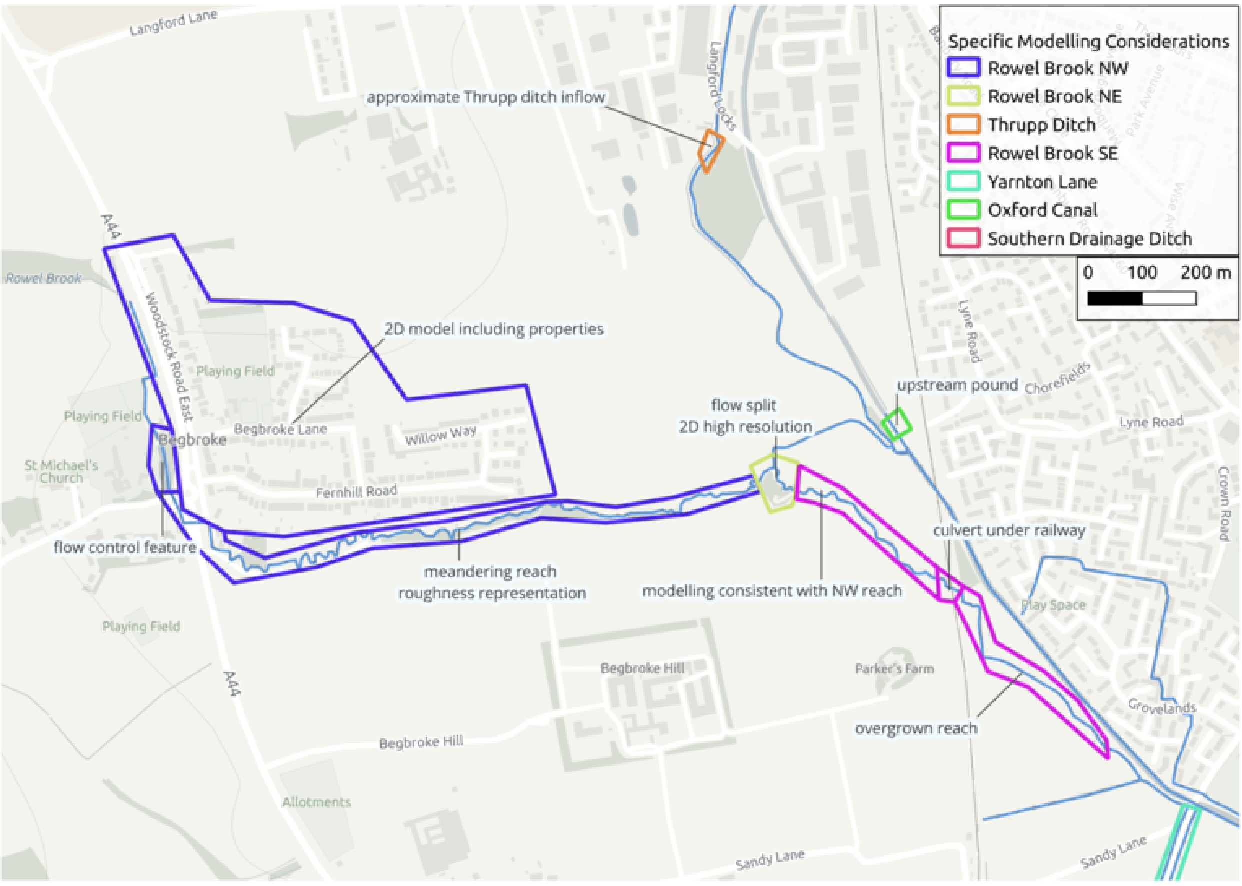

Figure 3.1: Some notable areas of the site (north).

3.2 Rowel Brook, NE

The flow split between the north eastern and south eastern branches of the Rowel Brook occurs in a small wooded area within the site boundary, close to its northern edge. The area is shown in pale green in figure 3.1. The primary channel currently appears to direct flows into the north eastern branch, but the south eastern branch's morphology suggests that it has been the principal low flow channel in recent times. As discussed above, this area also contains a number of ponds of uncertain history.

As the flow routes in this area of the model are very unclear, this area has been surveyed in very high detail with a view to modelling the area directly in 2D at high resolution using TUFLOW's QuadTree features. This should allow the model to inform the appropriate flow splits between the two branches of the Rowel Brook without the need for any explicit assumptions to be made.

The channels in this reach are generally straightened and are clearly man-made. There are several field crossings in various states of repair which will be explicitly modelled, as well as the culvert from this reach into the Oxford Canal. The water levels in this reach during the site visit appeared to be maintained by the pound level of the canal. This will be represented in the model by the use of initial water levels along this reach.

3.3 Thrupp Ditch

The upstream extent on the Thrupp Ditch will be located approximately 100m upstream of its confluence with the Rowel Brook and the site's red line. The exact location will be dependent on the analysis of the LiDAR and the detailed survey and will be chosen to ensure that any storage in the field north of the confluence is accurately represented by the model. The approximate location is shown in figure 3.1. This should give sufficient separation that any boundary effects do not have an impact on the site flood risk.

The hydrological inflow point will be located downstream (south) of the industrial estate and the inflow hydrograph will therefore not explicitly include any attenuation associated with flood risk measures, flow constrictions or flooding in the industrial estate or upstream.

Assumption 10. *The Thrupp Ditch catchment does not have significant attenuation.*

The Thrupp Ditch catchment upstream of the inflow point will be represented as a single point inflow with a ReFH2-derived hydrograph. This assumes that

A. The whole Thrupp Ditch catchment drains through the Thrupp Ditch and does not approach the site through an overland flow route or the canal.

B. The response of the Thrupp Ditch catchment is not significantly impacted by any designed flood attenuation scheme associated with the airport or industrial estate.

C. The culverted reaches in the industrial estate are sufficiently sized to convey the full peak of the hydrograph for all the design events or, in the alternative, the flows overtopping these culverts rejoin the Thrupp Ditch downstream are not significantly attenuated by traversing the industrial estate over-land.

These assumptions are generally conservative in terms of flood risk to the site, unless there is a significant risk of an overland flow route from this catchment approaching the site from the north, running west of the Thrupp Ditch. This eventuality should be identified by the DRM and an appropriate flow split can be determined if necessary.

3.4 Rowel Brook, SE

This reach of the Rowel Brook will be modelled broadly consistently with the NW reach. The culvert under the railway line is substantial and will be modelled directly. The reach downstream of the railway line appears to be considerably overgrown and will be modelled with a higher roughness until it discharges into a clearer and better-maintained ditch running parallel to the canal. This section of the brook is highlighted in magenta in figure 3.1.

3.5 Yarnton Lane

As highlighted above, the connectivity of the Yarnton Lane ditches, through the field drainage system to the south of the site is not currently clear and it is anticipated that this will be resolved by the detailed topographic survey. The key ditches forming this reach are shown in cyan in figure 3.3.

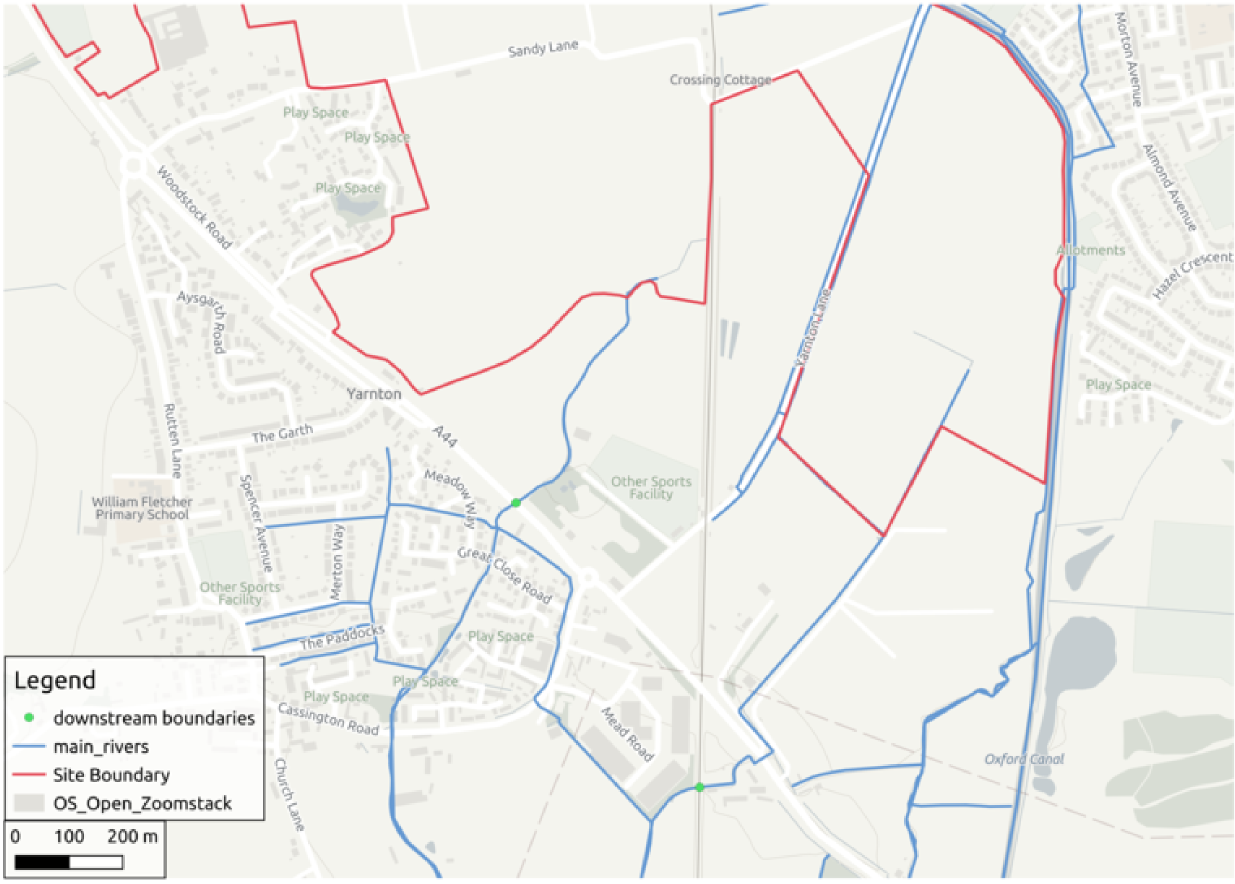

Figure 3.2: Downstream boundary locations

The downstream boundary of the Rowel Brook and the watercourses on the eastern part of the site will be taken at some point at or downstream of the A44 (outside of the site boundary). If survey is possible, this will be at the railway culvert shown in figure 3.2, but this may be moved upstream to the A44 crossing if access to the area is not available for survey.

3.6 Oxford Canal

The model will be bounded on the eastern side by the canal, which is assumed to be a hydrological barrier to flow (assumption 4). Site visits have indicated that there is no expected discharge into the canal from the East and a 1D model of the canal will therefore form the model's eastern boundary condition.

Two pounds of the canal will be modelled, from the lock just north east of the site (labelled on figure 3.1 to a point sufficiently downstream of the site. The exact downstream boundary location on the canal will be determined once survey data is available, but is likely to be the A44 crossing shown on figure 3.3.

The lock with associated side-spill weir and bypass channel located on the eastern boundary of the site will be modelled explicitly, allowing an understanding of whether flood flows entering the canal via the Rowel Brook are able to leave it and flood the site at this

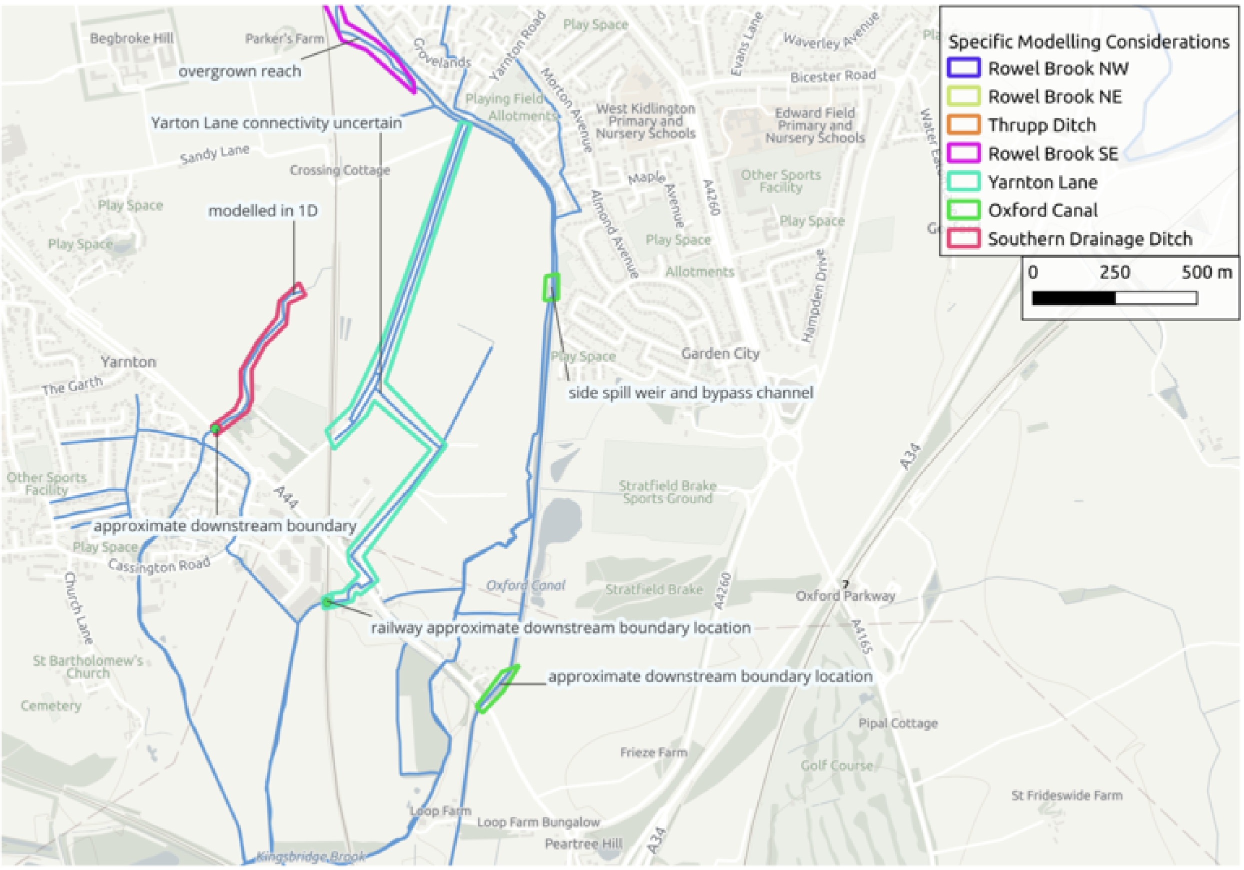

Figure 3.3: Some notable areas of the site (south).

location. This feature is shown on figure 3.3.

Assumption 11. *The canal does not carry significant flood flows originating elsewhere.*

The canal is assumed not to be carrying unusually high flows originating from catchments not discussed in this analysis during the design flood events. In general canals are not designed or intended to convey flood flows and it is considered to be beyond the scope of this work to identify other catchments upstream or downstream that might discharge into the canal, raising its water levels significantly beyond the maintained pound levels. The canal will be represented using one-dimensional modelling, allowing backwater effects from significant discharges into the canal originating from the Rowel Brook and Thrupp Ditch catchments to be modelled and, as discussed above, a sensitivity analysis will be undertaken to quantify the sensitivity of the model results to significant discharges into the canal originating from Kidlington. The downstream water level on the canal at the A44 will be assumed to be constant at the maintained pound level for the design events.

3.7 Southern Drainage Ditch

The southern drainage ditch will be modelled in 1D, and is likely to be represented hydrologically by a single sub-catchment that will be included as a point inflow at the upstream extent of the ditch. There may be an additional sub-catchment taking flows that from on and around the A44 that could be identified by the DRM. The downstream-most structure on the southern drainage ditch will be the road crossing under the A44 which is a relatively shallow, wide culvert, marked on figure 3.2.

Assumption 12. *Normal depth on the southern drainage ditch downstream of the A44*

There is no significant structure on the southern drainage ditch which is likely to cause a significant head loss as the ditch flows through Yarnton, downstream of the site, in a relatively well-maintained and recently-designed channel. It will be assumed that the gradient of the water surface in this reach will match the gradient of the channel, implying free flow downstream with no particular controlling structure or backwater effect reaching the site.

It should be noted that the catchment feeding this drainage ditch may be too small for the statistical method to be undertaken, and therefore the ReFH2 method may be relied upon for this catchment.

Appendix C CRT Correspondence

Gabriella Jordan

From:	Gareth Morgan <Gareth.Morgan@canalrivertrust.org.uk>
Sent:	21 November 2022 14:41
To:	Gabriella Jordan
Cc:	Enquiries TPWSouth
Subject:	RE: Oxford Canal Information Request
Attachments:	Standard response pack - Works query topic and location
Follow Up Flag:	Follow up
Flag Status:	Completed

****External Email. This email originated from outside Buro Happold.****

Hi Gabriella,

Based on the details provided, the information requested is in reference to two pounds, above Lock 43 & above Lock 44. No cross-sectional information is available currently. Our GIS system indicates no current outfalls/discharge points between Lock 42 & Lock 44. In reference to control levels, the pound above Lock 43 = 61,618m (AOD) & The pound above Lock 44 = 60,149m (AOD).

Any potential works will require review and approval from the Trust prior to any activities on site. I've attached our standard application pack, which details the initial process and includes the relevant documentation required to apply to Trust.

Any other queries, please get in touch.

Kind Regards

Gareth Morgan
Works Engineer

07586564175 **|** *Infrastructure Services South - LSE & WM Region - MK* **|** *gareth.morgan@canalrivertrust.org.uk*

Canal & River Trust Code of Practice
https://canalrivertrust.org.uk/business-and-trade/undertaking-works-on-our-property-and-our-code-of-practice

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From: Enquiries TPWSouth <Enquiries.TPWSouth@canalrivertrust.org.uk>
Sent: 17 November 2022 17:08
To: Gareth Morgan <Gareth.Morgan@canalrivertrust.org.uk>
Subject: FW: Oxford Canal Information Request

Hi Gareth,

Can you help with the below request – or are able to pass it to the right person?

Thanks,

Cate
Cate Davies
Technical Administrator
Infrastructure Services, Midlands & South

Canal & River Trust **|** Fradley Junction **|** Alrewas **|** Burton-upon-Trent **|** Staffs **|** DE13 7DN **|** Tel: 07484 548556 **|**

https://canalrivertrust.org.uk/business-and-trade/undertaking-works-on-our-property-and-our-code-of-practice

Please visit our website www.canalrivertrust.org.uk to find out more about us.

From: Gabriella Jordan <Gabriella.Panteli@BuroHappold.com>
Sent: 17 November 2022 09:53
To: Enquiries TPWSouth <Enquiries.TPWSouth@canalrivertrust.org.uk>
Cc: Clare Jones <Clare.Jones@BuroHappold.com>; gerald.morgan@edenvaleyoung.com
Subject: Oxford Canal Information Request

Dear Third Party Works Team,

I am writing regarding an information request for a section of Oxford Canal for a proposed development at Begbroke Innovation District, Oxfordshire (site plan attached). The site is located approximately five miles north of the centre of Oxford, between the villages of Begbroke, Yarnton and Kidlington (OX5 1PF). I have attached images of the Site and the stretch of the Canal that we are interested in.

We are looking to start building a hydraulic model to undertake detailed hydraulic modelling of our site to define the flood extents, as requested by the Environment Agency. To enable our modelling we are looking for the following information about the Oxford Canal. If this information is available and could be shared with us that would be greatly appreciated.

- Any cross-sections available along the stretch of canal identified in the attached image.
- Maintained pound levels for the pounds at the site and the pounds upstream and downstream, also the pound levels to the south of the polygon marked up by the A44.
- Any information of discharges into the canal including outfall locations.

Many thanks,
Gabriella

Gabriella Jordan
Water Engineer
Buro Happold | Cities | Water
www.burohappold.com | @burohappold

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Dilynwch ni ar https://twitter.com/canalrivertrust ac https://www.instagram.com/canalrivertrust

Appendix D Hydraulic Modelling Report

17TH JULY 2023

Hydraulic Modelling Report

Begbroke Innovation District

Prepared for:

Buro Happold
230, Lower Bristol Road,
Bath
BA2 3DQ

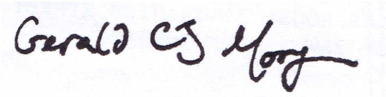
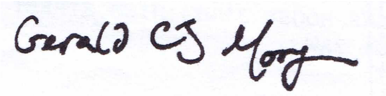
EdenvaleYoung

Edenvale Young Associates Ltd.
30, Queen Charlotte Street,
Bristol
BS1 4HJ
United Kingdom

Document Control

EdenvaleYoung

Report Title	Hydraulic Modelling Report
Project Name	Begbroke Innovation District
Project Number	EVY1077
Report Revision	C
Client	Buro Happold

Written by	Sally Hatton	May 19, 2023
Checked by	 Dr. Gerald C J Morgan	May 22, 2023
Approved by	 Dr. Gerald C J Morgan	July 17, 2023

Revision	Issued to	Date
A	Buro Happold	April 12, 2023
B	Buro Happold	May 22, 2023
C	Buro Happold	July 17, 2023

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INTRODUCTION

1. Project Overview

1.1 Project Requirements

Edenvale Young Associates have been commissioned by Buro Happold to undertake hydraulic modelling at a site west of Kidlington, Oxfordshire. The results of this hydraulic modelling will be used to inform a Flood Risk Assessment (FRA) for the proposed Begbroke Innovation District—a mixed use development incorporating the existing Begbroke Science Park. The site boundary is shown in figure 1.1, along with a summary of watercourse locations. The watercourses have been subdivided into a series of reaches for the purposes of this report and the naming used for these reaches is also shown in this figure.

The purpose of the study is to define the flood extents and map the flood depths associated with a set of key design events required for the planning process, specifically the 3.33%, 1% and 0.1% AEP present day events and the 1% AEP event with climate change allowances to the 2080s from Gloucestershire and the Vale Management Catchment. These events are shown in table 1.1.

AEP	Epoch	Estimate	Uplift
3.33%	Present		0%
1%	Present		0%
1%	2080s	Central	26%
1%	2080s	Higher	41%
0.1%	Present		0%

Table 1.1: *Fluvial events to be simulated*

1.2 Purpose of this Report

This report seeks to

- provide an overview of the site and the local watercourses that could impact on the site's flood risk;
- describe the peak flow hydrological analysis undertaken for the site and how those inflows are distributed across the site;
- describe the hydraulic modelling methodology and how particular key features of the site and its local watercourses have been simulated;
- present the results of the baseline modelling exercise and sensitivity tests;
- present modelling of proposed mitigation options
- outline key assumptions associated with the model build and results.

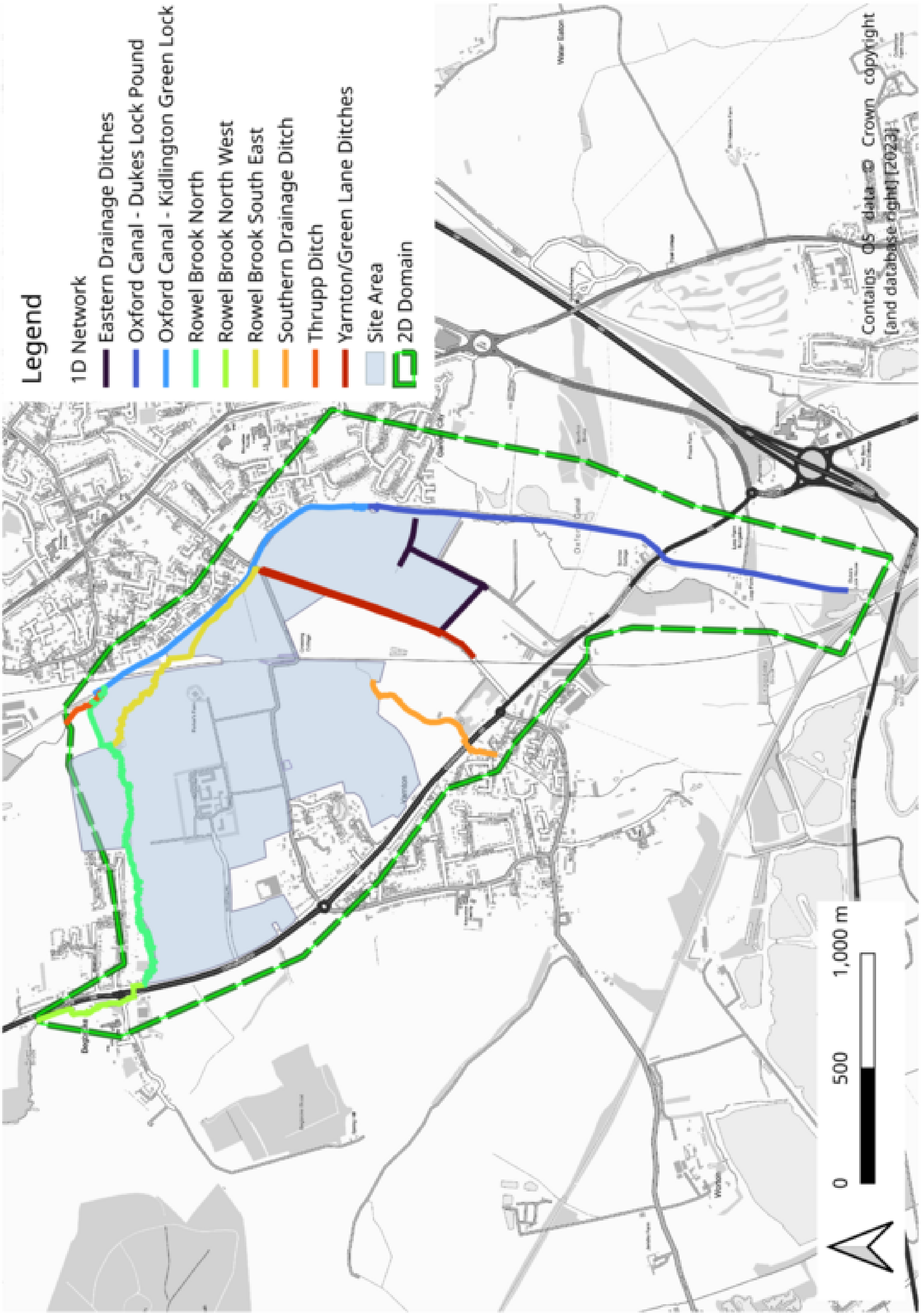

Figure 1.1: Site boundary and nearby watercourses

2. Description of the Site

2.1 Overview

There are a number of watercourses on and adjacent to the site. These include the Rowel Brook, the Thrupp ditch, the Southern Drainage Ditch, the Eastern Drainage Ditches as well as other field ditches. The location of these watercourses is shown in figure 1.1. To the east, the site is bounded by the Oxford Canal.

This section of the report sets out the key characteristics of each watercourse. This has been informed by two site visits, which were undertaken in October 2022 and March 2023 to help better understand the connectivity of the channels and inform the model build. Flow conditions within the watercourses were notably different on each occasion; in October, many of the channels were dry whilst in March, flow was evident in the majority of channels.

2.2 Rowel Brook: North West and North

The Rowel Brook originates west of Oxford Airport and drains east to the A44, Woodstock Road, before turning south towards Begbroke village. Once at Begbroke, the Rowel Brook is culverted under the road and flows east across the northern boundary and through the north western corner of the proposed development site. Within this reach the channel is comparatively sinuous. These reaches are referred to in this report as the Rowel Brook North West and Rowel Brook North.

This watercourse appears to be ephemeral, having no flow or standing water at the time of the initial site visit, but with a visible flow when the second site visit was undertaken. The watercourse bifurcates in a small wooded area to the north of the proposed development. The ground levels in this wooded area are variable and there was no obvious low-flow connection to the Rowel Brook South East. Similarly, a number of ponds in this location did contain water behind a weir that would seemingly discharge into the Rowel Brook South East, but there was no obvious connection from these ponds to the Rowel Brook North.

A topographic survey has been undertaken in this area to better understand likely flow paths and surface water connections during high flow conditions. The Rowel Brook North flows north east from the copse and appears to discharge into the Oxford Canal via a culvert shortly after its confluence with the Thrupp Ditch. This branch contained standing water during the initial site visit, but visible flow during the second site visit.

2.3 Rowel Brook, South East and Yarnton/Green Lane Ditches

The Rowel Brook South East branch flows in a south easterly direction through the site and, after passing through a culvert under the railway line, along the site's eastern edge. After crossing under

Sandy Lane it flows along the western side of Yarnton/Green Lane. Observations on site, along with the topographic survey, indicated that flow from the Rowel Brook is only routed along the western side.

The ditches along Yarnton/Green Lane appeared poorly maintained and the connectivity between the ditches was not always clear. A culvert close to the confluence with the Eastern Drainage Ditches appears to convey water from west to east below Yarnton/Green Lane, but water in either ditch was limited during the site visits and therefore this hypothesis is unconfirmed. This culvert is shown in figure 2.1. Section 4.8 outlines the assumptions made for these ditches.

Figure 2.1: *Culvert assumed to convey water from the western to eastern ditch along Yarnton/Green Lane*

2.4 Eastern Drainage Ditches

The watercourse is finally routed from Yarnton/Green Lane into field drainage ditches, which are referred to here as the Eastern Drainage Ditches. This flow route is assumed as the confluence between the Yarnton/Green Lane and the Eastern Drainage Ditch was dry during both site visits, but the morphology of the channels suggested that the dominant flow route during high flows would be into the eastern ditch system. During the second site visit, flow was evident in ditches closer to the canal and it was clear that this flow was eventually routed back towards the A44, south of the site. It was not possible to access this area for detailed survey. Figure 2.2 shows flow within the ditch system looking downstream.

Figure 2.2: *Eastern Drainage Ditch system looking downstream in a south-westerly direction. The solar farm is visible on the left bank.*

Prior to the acquisition of topographic survey there was some uncertainty associated with the connectivity of the ditches either side of Yarnton/Green Lane. Some uncertainty remains, but it is now considered that:

- only the western channel along Yarnton Lane is connected to Rowel Brook at the upstream extent.
- flow along along both sides of Yarnton Lane is not continuous, with significant vegetation growth and debris blockages.
- the channels are connected to each other at their southern end via a culvert as shown in the watercourse map.
- the Eastern Drainage Ditches are eventually connected to the return crossing under the A44 via field drains to the east
- the Eastern Drainage Ditches are not directly connected into the Oxford Canal.

2.5 Thrupp Ditch

The Thrupp Ditch drains a catchment north of the site and flows south through an industrial estate, east of Oxford Airport. It runs just west of the Oxford Canal, flowing south, before entering a culvert under a footpath and joins with the Rowel Brook North and, shortly downstream, the Oxford Canal.

2.6 Oxford Canal

Figure 2.3: *Side spill at Kidlington Green Lock*

The Oxford Canal runs in a southerly direction from the northeast of the site, down the eastern edge of the site boundary. There are two pounds that affect the site. The most significant runs from Roundham Lock - just upstream of the confluence with the Rowel Brook and Thrupp Ditch - along the eastern boundary of the site to Kidlington Green Lock. The second pound starts here and runs south for a considerable distance, ending a short way upstream of the A40 at Dukes Lock.

Kidlington Green Lock has a substantial upstream side-spill weir, shown in Figure 2.3, to maintain the upper pound level. This discharges into a parallel channel around the lock on the western side and returns to the canal downstream. It should be noted that, whilst a field drainage ditch runs perpendicular to this offtake, it did not appear to be connected to the bypass channel. A similar structure can be observed at Dukes Lock in aerial photography, but no detailed survey was available.

2.7 Southern Drainage Ditch

The Southern Drainage Ditch originates to the west of the railway within the site boundary and flows southwest, beneath the A44 Woodstock Road and through Yarnton village, with no connections upstream.

MODELLING

3. Peak Flow Estimation

3.1 Overview

A full hydrological analysis has been undertaken in order to derive design flow hydrographs to be implemented as boundaries to the hydraulic model for the required events. Full details of the hydrological analysis are provided in the Flood Estimation Report (appendix A) included with this report. The analysis has been carried out in accordance to the requirements set out by current Environment Agency guidelines[1] and the FEH (Flood Estimation Handbook). Therefore, both the FEH Statistical and ReFH2 rainfall-runoff approaches have been applied for the purposes of the hydrological analysis. However, this has also been aided by the implementation of a Direct Rainfall Model (DRM) of the area of study.

The Flood Estimation Report covers the conceptual model and selection of estimated locations for the main watercourses, namely the Rowel Brook, Thrupp ditch and Southern Drainage ditch. Details of the FEH analysis at the locations selected for the purposes of flood estimation on these watercourses are also provided in the appendix. The intervening area at the downstream boundary of the model has been split into sub-catchments, according to the DRM results. Details of the DRM built to refine the FEH analysis and a summary of its outputs are provided in section 3.2. A summary of the FEH analysis outputs is provided in section 3.3.

3.2 Direct Rainfall Model

Due to limitations associated with the resolution at which the FEH catchments can be defined and to the characteristics of the topography of the area, it was necessary to refine the delineation of the overall runoff contributing area to the site of interest and to gain a better understanding of the surface flow routes which might affect the estimation of flood risk at the site. For this purpose, a broad scale 2D Direct Rainfall Model (DRM) has been built in TUFLOW version 2020-10-AC using LiDAR DTM data. Minor modifications were made to the topography based on-site observations and the topographic survey in order to ensure that a representative flow path was identified. Variations to 2D roughness values were applied to reflect different surface coverage within the model domain.

The model has been run with the 0.1% Annual Exceedance Probability design rainfall and evaluated in terms of unit flow and velocity modelled outputs within the 2D model domain. This process has allowed the refinement of the FEH catchment boundaries and the delineation of on- and off-site sub-catchments to be taken into account for the purposes of the hydraulic modelling.

The final contributing areas for the Rowel Brook, Thrupp ditch and Southern Drainage ditch, delineated as a result of the refinement of the FEH boundaries on the basis of the DRM results, are shown in

[1]LIT11832 Environment Agency Flood Estimation Guidelines, published 23/12/2022

figure 3.1. The overall contributing catchment downstream of the site of interest (at Kingsbridge, KB01) is also shown in figure 3.1.

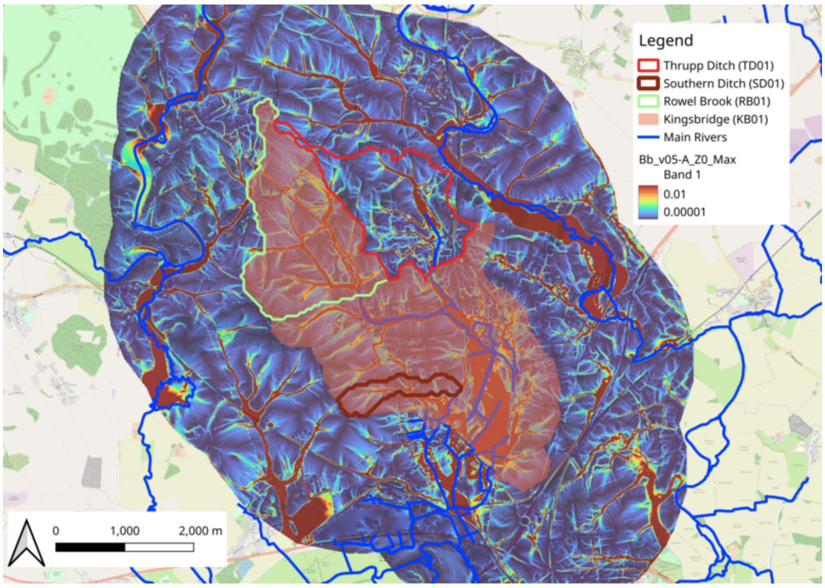

Figure 3.1: *Final contributing catchments at the locations selected for FEH analysis and the Direct Rainfall Model unit flow results*

Figure 3.2 shows the sub-catchments delineated as a result of the DRM outputs analysis. It should be noted that, according to the results of the DRM, the sub-catchment S08 has been identified as providing the most accurate representation of the runoff contributing to the Southern Drainage ditch.

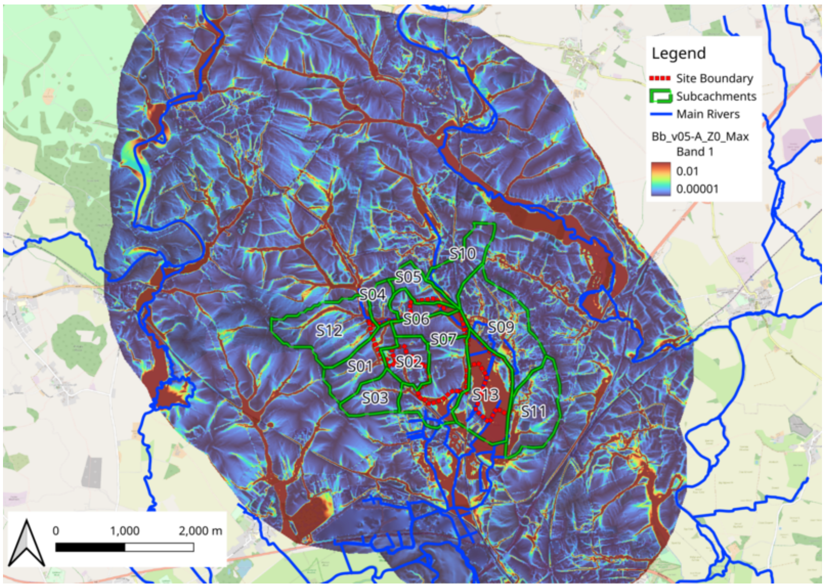

Figure 3.2: *Sub-catchments delineated using the DRM results for which lumped or distributed inflows are being incorporated in the hydraulic model.*

A summary of the final contributing areas for the estimation of the main inflows on the Rowel Brook (RB01), Thrupp ditch (TD01) and Southern Drainage ditch (SD01) is provided in table 3.1. The areas of all sub-catchments and the total contributing area at KB01 are also detailed in table 3.1. It should be noted that the sum of all contributing areas at the main estimate locations and for all sub-catchments accounts for about 90% of the total contributing area at KB01.

Node ID	Area (km^2)
KB01	14.056
RB01	3.55
TD01	2.67
SD01 (=S08)	0.811
S01	0.546
S02	0.382
S03	0.369
S04	0.189
S05	0.265
S06	0.221
S07	0.351
S09	1.076
S10	0.464
S11	0.757
S12	0.963
S13	0.894
Total	12.614

Table 3.1: *Contributing areas at main estimate locations and for all sub-catchments*

3.3 FEH analysis outputs

Q peak estimates

Final Q peak estimates at RB01, TD01, and SD01 are the statistical estimates. QMED has been estimated from catchment descriptors and adjusted by donor transfer and for urbanisation. Q peaks for events with AEP $< 50\%$ have been estimated by applying growth factors derived from pooled analysis at KB01. It should be noted that the peak estimates for all sub-catchments have been obtained from Qpeaks estimated at KB01, scaled by the ratio of catchment areas. A summary of Qpeaks for all AEPs(%) is provided in table 3.2.

% AEP	Return Period	KB01	RB01	TD01	SD01	S01	S02	S03	S04	S05	S06	S07	S09	S10	S11	S12	S13
50	2	0.891	0.180	0.176	0.120	0.035	0.024	0.023	0.012	0.017	0.014	0.022	0.068	0.029	0.048	0.061	0.057
20	5	1.306	0.263	0.258	0.177	0.051	0.035	0.034	0.018	0.025	0.021	0.033	0.100	0.043	0.070	0.089	0.083
10	10	1.615	0.326	0.319	0.218	0.063	0.044	0.042	0.022	0.030	0.025	0.040	0.124	0.053	0.087	0.111	0.103
3.33	30	2.171	0.438	0.429	0.294	0.084	0.059	0.057	0.029	0.041	0.034	0.054	0.166	0.072	0.117	0.149	0.138
2	50	2.471	0.498	0.488	0.334	0.096	0.067	0.065	0.033	0.047	0.039	0.062	0.189	0.082	0.133	0.169	0.157
1	100	2.932	0.591	0.579	0.396	0.114	0.080	0.077	0.039	0.055	0.046	0.073	0.224	0.097	0.158	0.201	0.186
0.5	200	3.466	0.699	0.684	0.469	0.135	0.094	0.091	0.047	0.065	0.054	0.087	0.265	0.114	0.187	0.237	0.220
0.2	500	4.308	0.869	0.851	0.583	0.167	0.117	0.113	0.058	0.081	0.068	0.108	0.330	0.142	0.232	0.295	0.274
0.1	1000	5.068	1.022	1.001	0.685	0.197	0.138	0.133	0.068	0.096	0.080	0.127	0.388	0.167	0.273	0.347	0.322
QBAR		0.953	0.193	0.188	0.128	0.037	0.026	0.025	0.013	0.018	0.015	0.024	0.073	0.031	0.051	0.065	0.061

Table 3.2: *Qpeak estimates (m^3/s) at main estimate locations and sub-catchments*

Design Hydrographs

Design hydrographs have been derived as ReFH2 hydrographs scaled to match the statistical peaks. For this purpose, two storms applied consistently across the area of interest to the analysis have been selected, and these are detailed in table 3.3. The storms have been estimated from ReFH2 analysis as representative of the critical storm conditions for fast response hydrological features at the site location (SD=3.5hrs) and for the wider watershed including the site (SD=11hrs).

Storm Duration (hr)	DDF Model	Storm Area (km^2)	Areal Reduction Factor (ARF)
3.5	DDF13	0.811	0.977
11	DDF13	14.056	0.96

Table 3.3: *Summary of design storms*

MODELLING

4. Hydraulic Modelling

4.1 General Modelling Approach

The hydraulic model was constructed using ESTRY-TUFLOW. ESTRY was selected for the 1D component of the model due to the meandering, shallow gradient and ephemeral nature of the Rowel Brook and other watercourses. The model has been run using TUFLOW version 2020-10-AF and the HPC solver. Due to the comparatively small peak flows derived by the hydrological analysis, the model has been run using double precision.

4.2 Model Extent

The model domain is shown in figure 4.1, bounded by the green line. This extent fully covers the site of interest and extends upstream on the Rowel Brook and its tributaries as well as downstream as far as is practical. This image also shows the extent of the 1D network and the small number of channels have been represented in 2D.

The majority of the Digital Terrain Model (DTM) uses LiDAR data downloaded from the DeFRA website. In some locations, as described below, this has been superseded using detailed topographic survey. The model uses a 2m cell size throughout.

4.3 Representation of Channels

The mid-point approach for ESTRY cross section representation has been used. This approach reduces the amount of interpolation of data performed by the ESTRY solver and provides a representation of the channels that is closer to the surveyed data. This approach has also allowed a high detail model to be achieved through the use of a river centre-line that allows the modelled bed level to vary significantly between cross-sections.

Structures have been modelled using the appropriate channel type based on the supplied topographic survey. Figure 4.2 shows the extent of the 1D ESTRY network included within the model and the use of different channel types.

4.4 Topographic Survey

Detailed topographic survey of the site, including cross-sectional survey of channels and structures, was undertaken in early 2023 and this has been incorporated into the model build.

The river centreline was surveyed at a 2m spacing along each channel (coarser along the Oxford Canal) which has allowed critical high and low points in each channel to be identified and included in the modelling even where full cross-sections are not available at those locations.

Wider topographic survey of the site has also been undertaken. A Triangulated Irregular Network (TIN) based on this information has

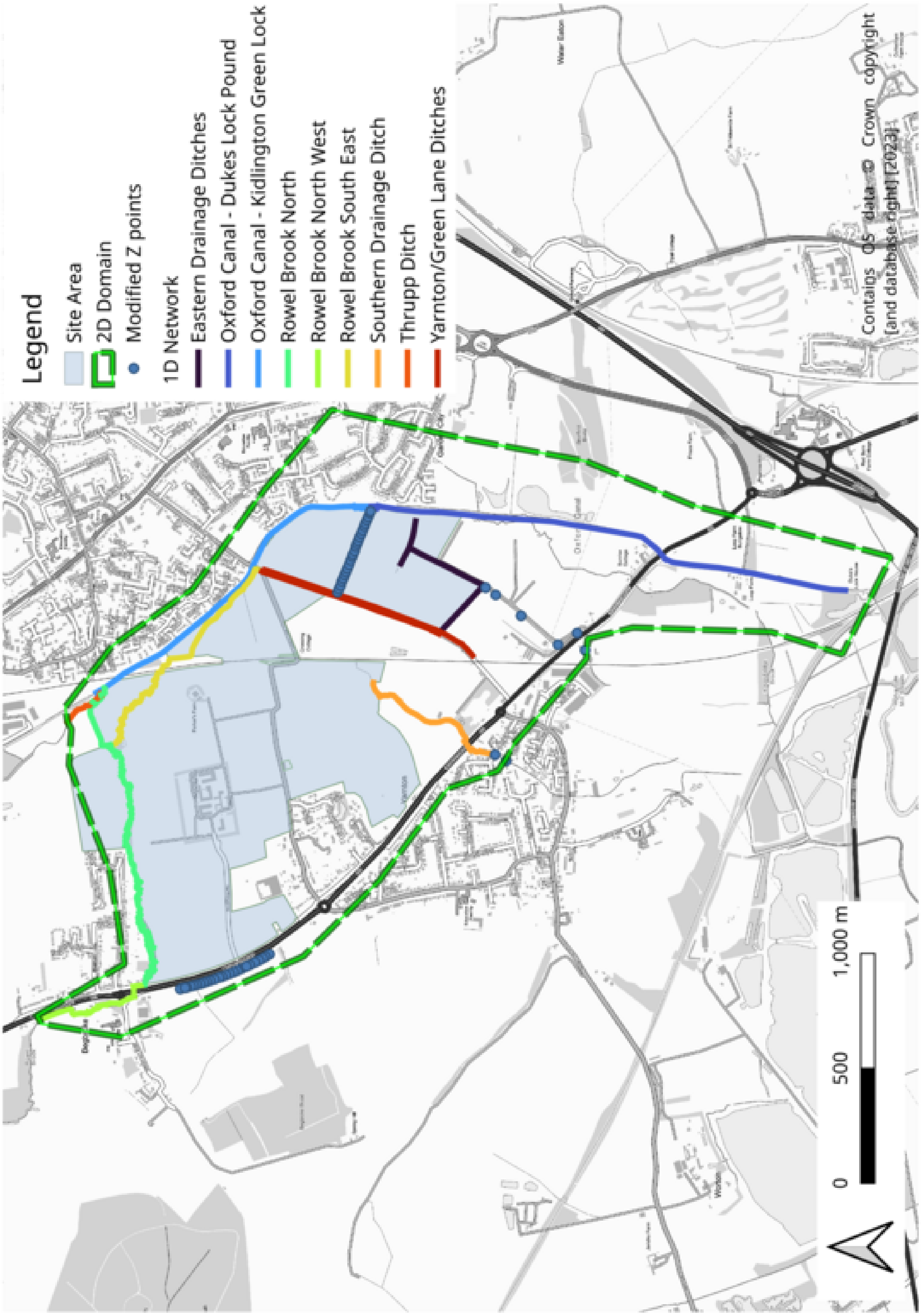

Figure 4.1: *Model domain and 1D/2D channels*

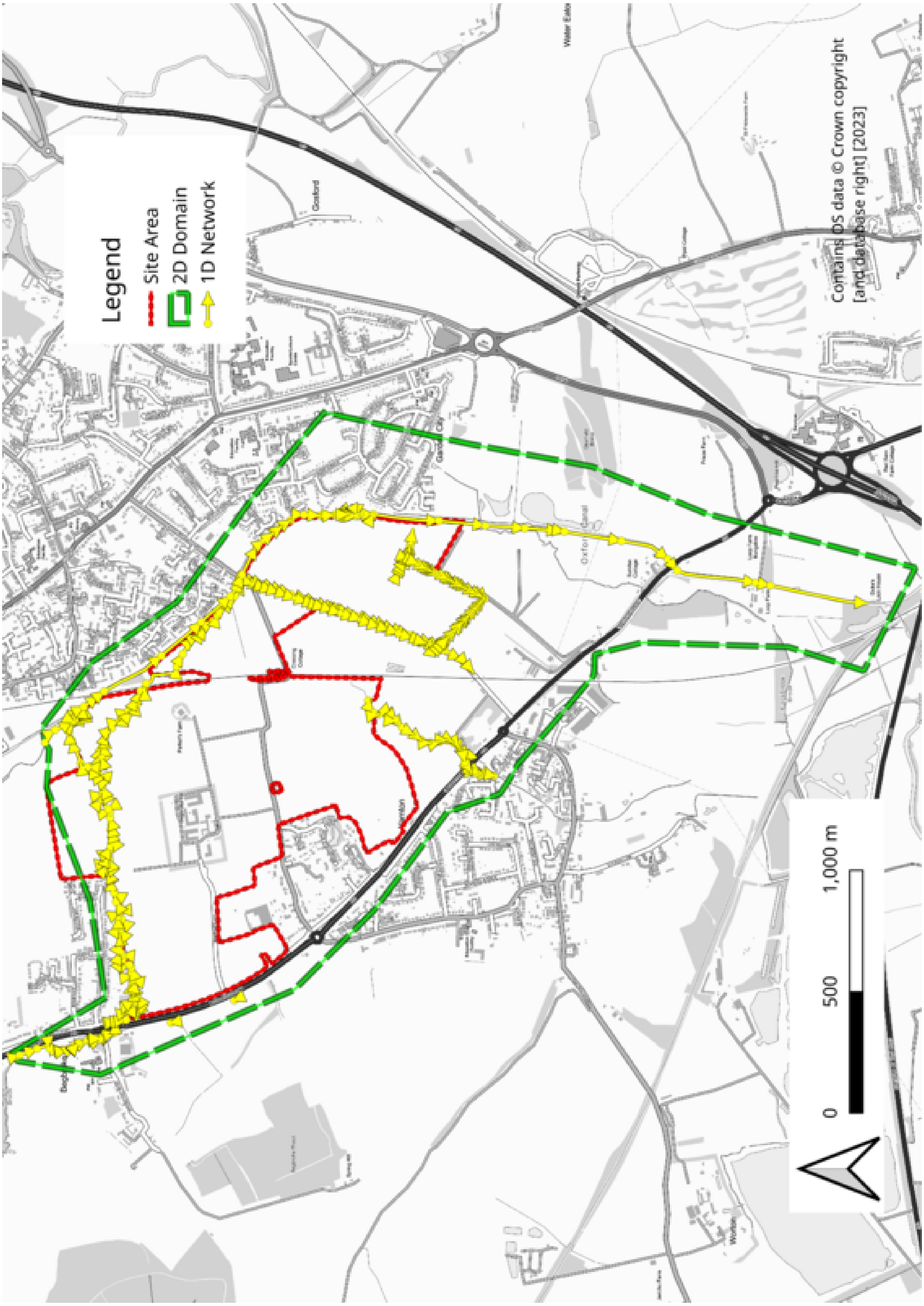

Figure 4.2: *Model domain and 1D channels*

Watercourse	Roughness	Commentary
Rowel Brook, North West	0.04 - 0.07	Particularly overgrown at upstream extent
Rowel Brook, North	0.0805	Based on Cowan's method
Rowel Brook South East	0.07 - 0.0805	
Thrupp Ditch	0.07	
Oxford Canal	0.03	
Southern Drainage Ditch	0.05 - 0.07	Limited photographic evidence available. Consistent with other ditches on site
Green/Yarnton Lane Ditches	0.07	pBlockage attribute also utilised
Eastern Drainage Ditches	0.04 - 0.07	Recent vegetation clearance evident on some reaches

Table 4.1: *1D Model roughness values*

been applied in some targetted locations, as described later in this report.

4.5 Other Topographic Modifications

Banklines have been applied along most watercourses, based on a combination of cross-sectional and bank top survey, to ensure that the onset of flooding from these channels is accurately represented. This ensures that water will spill from the 1D domain into the 2D domain at an appropriate elevation.

As shown in figure 4.1, a number of drainage ditches were identified on-site but detailed cross-sectional survey was not available in all locations. In these instances, channels have been represented in the 2D model based on an approximate channel width. Bed elevations have been set using channel bed survey where available.

4.6 Hydraulic Roughness Values

Hydraulic roughness coefficients have been applied based on representative reaches of the channel observed during the site visit. Table 4.1 sets out the 1D roughness values for the modelled reaches within the model.

To account for the very high sinuosity of the Rowel Brook as it runs across the northern edge of the site, Cowan's method was used to determine an appropriate roughness coefficient.

Table 4.2 sets out the roughness parameter values in the 2D domain. These are based on Edenvale Young's standard TUFLOW modelling template, giving consistency with a large number of existing models in the UK, many of them well-calibrated to observed data.

Material	d_1	n_1	d_2	n_2
General	0.1	0.5	0.2	0.05
Roads	–	0.02	–	–
Trees/ Wooded	0.1	1.0	0.2	0.1
Buildings	–	1.0	–	–
Water-course	–	0.035	–	–
Ditches	–	0.065	–	–

Table 4.2: *2D Model roughness values*

4.7 Model Boundaries

Figure 4.3 shows the location of the key model inflows. These have been selected with reference to the direct rainfall model to best simulate how water from each of the subcatchments is expected to reach the channels. The majority of the subcatchment inflows are applied as point inflows to the 1D domain; one inflow (S06) is distributed across a reach of the Rowel Brook North and two inflows (S01 and S07) are applied directly to the 2D domain.

4.8 Watercourse Specific Considerations

Rowel Brook, North West

The upstream modelled extent on the Rowel Brook is located adjacent to Woodstock Road, upstream of Begbroke village, as shown in figure 1.1. This location was determined by the upstream extent of the detailed topographic survey and the reach incorporates a number of structures and features which are expected to provide a flow control upstream of the site. The culverts under the A44 at the north western corner of the site have been explicitly modelled in the 1D network, connecting the Rowel Brook North West reach to the Rowel Brook North.

It was noted that the uppermost reach of the watercourse, to the west of Woodstock Road, was particularly overgrown. This reach has been applied a higher roughness value than the majority of the Rowel Brook North West.

Rowel Brook, North

The Rowel Brook meanders along the northern boundary of the site and south of Fernhill Road. The channel is notably sinuous in this location. Modelling individual meander bends in quick succession can result in stability issues as water rapidly passes between 1D and 2D components of the model. To avoid this, the sinuosity of this channel has been represented using Manning's "n" roughness values. An appropriate Mannings "n" value was determined using the estimation method described in Cowan (1956)[1], which considers channel sinuosity. As such, in the Rowel Brook North, a roughness value of 0.0805 is applied to the channels.

The flow split between the north eastern and south eastern branches of the Rowel Brook occurs in a small wooded area within the site boundary, close to its northern edge. The connectivity of channels in this location was uncertain, although direct connectivity during normal flow conditions was not observed on either site visit. A surface DTM was supplied for incorporation into the model in this area and has been integrated into the model, superseding the LiDAR and setting the elevation of the boundary cells on the right bank of the Rowel Brook. This means that the direction of flow within the

[1] Cowan, W.L. Systematic Method for Estimation Roughness Coefficients. Agricultural Engineering. 1956

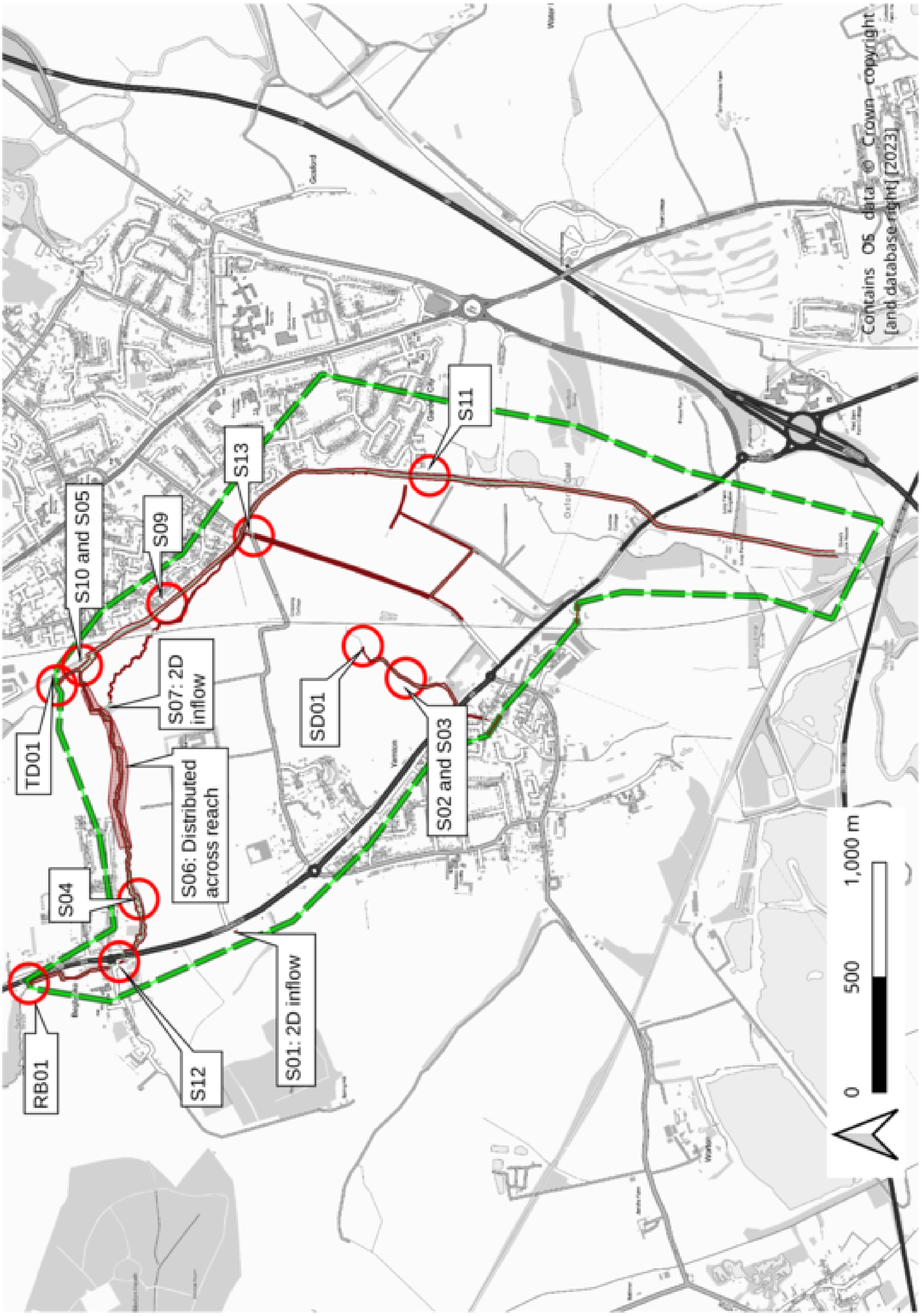

Figure 4.3: *Location of model inflows*

copse during high flows events is determined hydraulically rather than by assumptions made during the model build.

An Initial Water Level (IWL) consistent with the downstream weir crest has been applied to the pond in the copse area. The pond and weir are shown in figure 4.4. This is considered conservative and means that the 2D inflow located within the pond will immediately initiate overtopping of the weir.

Figure 4.4: *Pond and weir crest within copse*

The Rowel Brook North is connected to the Thrupp Ditch immediately upstream of Oxford Canal in the far northern corner of the site. Prior to their confluence, the two watercourses run either side of a footpath, which has been modelled in 1D using a weir channel rather than in 2D. The Rowel Brook North eventually connects to the Oxford Canal.

Thrupp Ditch

The upstream extent on the Thrupp Ditch is located approximately 180m upstream of its confluence with the Rowel Brook and the site's red line.

The hydrological inflow point is located downstream (south) of the industrial estate and the inflow hydrograph therefore does not explicitly include any attenuation associated with flood risk measures, flow constrictions or flooding in the industrial estate or upstream. This is a conservative assumption.

Rowel Brook, South East

This reach of the Rowel Brook has been modelled consistently with the North and North West reaches. The culvert under the railway line has been modelled as open channel, but results were checked to ensure that the soffit height of the culvert was not exceeded during modelled flood conditions. The reach downstream of the railway was considerably overgrown and has been modelled with a comparatively high roughness value until it discharges into a clearer and better-maintained ditch running parallel to the Oxford Canal.

Figure 4.5: *Example of the condition of the ditches running parallel to Yarnton/Green Lane*

Yarnton/Green Lane

The parallel ditches running either side of Yarnton/Green Lane have been modelled as separate 1D model elements; the road itself is modelled in 2D.

As noted previously, the channels either side of Yarnton/Green Lane are poorly maintained. Observations made during the site visit also indicated that the flow path along the ditches may not be continuous, although it was not possible to assess all instances of channel blockage on the site visit. To provide some representation of this, the pBlockage attribute has been included in some network lines along both the western and eastern ditches, applying intermittent 50% blockages to the channels. An example of the condition of the ditches is shown in figure 4.5.

The southern extremities of both ditches - beyond the confluence with the Eastern Drainage Ditch System - terminate where the cross-sectional survey ends. No water was visible here on either site visit.

Eastern Drainage Ditches

The Eastern Drainage Ditch system connects to the Yarnton/Lane Ditches at the confluence shown on figure 1.1 via the 1D network in this location. Some stretches of the ditch system appear to have been recently cleared, as shown in figure 4.6 and lower roughness values have been applied here compared to other ditches within the model.

The downstream extent of the Eastern Drainage Ditches—which may be considered as a continuation of the Rowel Brook South East—was not surveyed due to access constraints. The culvert shown in figure 4.7 has been included as part of the 1D network but subsequently discharges into the 2D domain via an SX boundary. The channel downstream of this location has been represented in the 2D domain to ensure a continuous flow path but bed elevations have been estimated from LiDAR. Any structures which may be present have not been included due to lack of survey. The structure which conveys the ditch beneath the A44 Woodstock Road has been modelled as open channel as it assumed that the road crossing does not represent a constriction. On this basis, model results in this location should be viewed with caution, but this should not affect the conclusions of this report as the area lies outside the site boundary.

The downstream boundary of the Eastern Drainage Ditches has been modelled with a HQ boundary in 2D. A slope of 0.01 has been applied.

Figure 4.6: *Example of apparent recent vegetation clearance along the Eastern Drainage Ditch system*

Figure 4.7: *End of 1D network along Eastern Drainage Ditch*

Oxford Canal

Two pounds of the canal have been modelled, from Roundham Lock just north east of the site to Duke's Lock approximately 900m downstream of the A44. These pounds are shown on Figure 1.1. Cross sectional survey of the canal was specified to be sparse as the geometry is largely consistent throughout the modelled reach. Where constrictions were observed on aerial photography and had not been surveyed, estimates of the width of the canal were made from aerial photography with a simple rectangular channel profile created to represent these locations. The bed level of the canal in the supplied cross-sections has been manually adjusted to an assumed water depth of 1.5 metres, based on engineering judgement. The initial water levels (IWLs) in the pounds were based on information from the Canal and Rivers Trust and set out in table 4.3.

Kidlington Green Lock is located midway along this reach and adjacent to the site. A significant side-spill weir at Kidlington Green Lock has been modelled explicitly, which helps understand whether flood flows entering the canal via the Rowel Brook further upstream

Lock Name	Pound Level (mAOD)	IWL (mAOD)
Kidlington Green Lock	61.618	61.618
Duke's Lock	60.149	60.25

Table 4.3: *Canal pound levels and modelled initial water levels*

are able to leave the canal and flood the site from this location. The bypass channel itself has been modelled in 2D based on surveyed channel bed levels, with reconnection to the canal downstream of the lock included as a 1D element.

Aerial photograph indicates that a similar offtake structure exists at Duke's Lock. No topographic survey was available Duke's Lock to model this in detail. Instead, an IWL 0.1m higher than the maintained pound level was included as a HT boundary. This increase above the maintained pound level will allow for some superelevation of the downstream water levels due to flood flows.

The modelling shows flooding along the left bank of the canal, downstream of Kidlington Green Lock. It should be noted that detailed topographic survey was limited along the left bank of the canal and therefore information on bank heights in this location is sparse. Whilst banklines set the elevation of boundary cells along the left bank of the canal, the model does not represent local variation in elevation and therefore the flood extents in this area should be viewed with caution. It should, however, be noted that the area that should be viewed with caution is outside the site boundary.

The canal is assumed not to be carrying unusually high flows originating from catchments not discussed in this analysis during the design flood events. In general canals are not designed or intended to convey flood flows and it is considered to be beyond the scope of this work to identify other catchments upstream or downstream that might discharge into the canal, raising its water levels significantly beyond the maintained pound levels. The canal has been represented using 1D modelling, allowing backwater effects from significant discharges into the canal originating from the Rowel Brook and Thrupp Ditch catchments to be modelled.

Southern Drainage Ditch

It was not possible to access most of the Southern Drainage Ditch and therefore on-site observations could not be used to inform the application roughness values. Mannings 'n' roughness values have been estimated based on the limited number of photographs available and with consideration of the maintenance of other ditches on-site. The downstream boundary has been modelled using a HQ boundary in the 2D domain with a gradient of 0.01.

Road and Other Ditches

Overland flow from Begbroke Hill, to the west of the site, is a plausible flood mechanism that may result in overland flow reaching the site. A number of drainage ditches run along the west of Woodstock

Road which may intercept overland flow originating on Begbroke Hill. Whilst detailed cross-sectional survey was unavailable, the elevations for the bottom and top of bank were supplied for these ditches; this has been used to model the ditch in the 2D domain. Given the 2m cell size, a cell width factor (CWF) was applied to the area in order to better reflect the actual flow width of this ditch. Figure 4.1, highlights the location of the road ditches explicitly included within the model. It should be noted that, given the available information, there is some uncertainty associated with the capacity of this ditch.

RESULTS

5. Hydraulic Model Results

5.1 Baseline Model Results

Figures 5.1–5.5 show the maximum depth results from each of the modelled design events with the longer, 11-hour storm duration. Equivalent results for the shorter, 3.5-hour storm duration are shown in figures 5.6–5.10.

The majority of out of bank flooding is located towards the east of the site, close to Oxford Canal. This is not unexpected, as the Eastern Drainage Ditches where much of the water from the site is routed, do not appear to be designed with extreme flood risk in mind. The flood extents in this area should be viewed with some caution as much of the channel that would drain this area was not surveyed due to access constraints, and it is therefore possible that, if this channel was particularly well-maintained, the flood extents in this area would be less.

The model shows significant flooding to Kidlington from the east bank of the Oxford Canal, outside of the site boundary. This is predominantly driven by the flows from the Rowel Brook and Thrupp Ditch which discharge into the canal and cause a backwater from Kidlington Green Lock—a structure which was likely not designed to handle such high flows.

Flooding associated with the Rowel Brook North is typically confined to a narrow corridor either side of the channel. In the largest events, a shallow flow route fed by run-off from Begbroke Hill overtops Woodstock Road from the west and crosses the north west corner of the site.

The Southern Drainage Ditch is shown to cause out-of-bank flooding in adjacent fields, particularly on the right bank. Water ponds upstream of the Woodstock Road although the road is not shown to overtop.

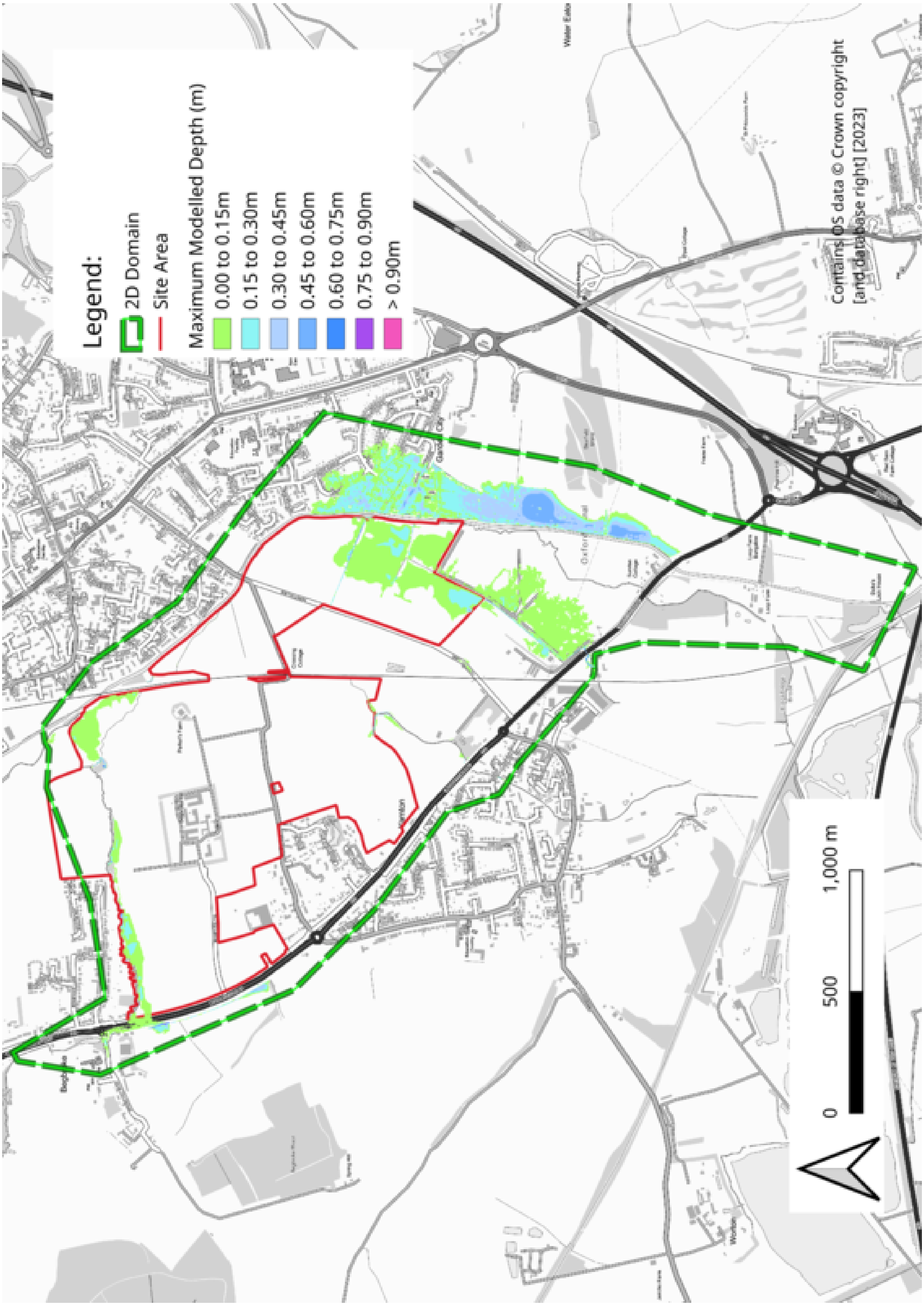

Figure 5.1: Maximum modelled depth in the 3.33% AEP event, 11 hour storm duration

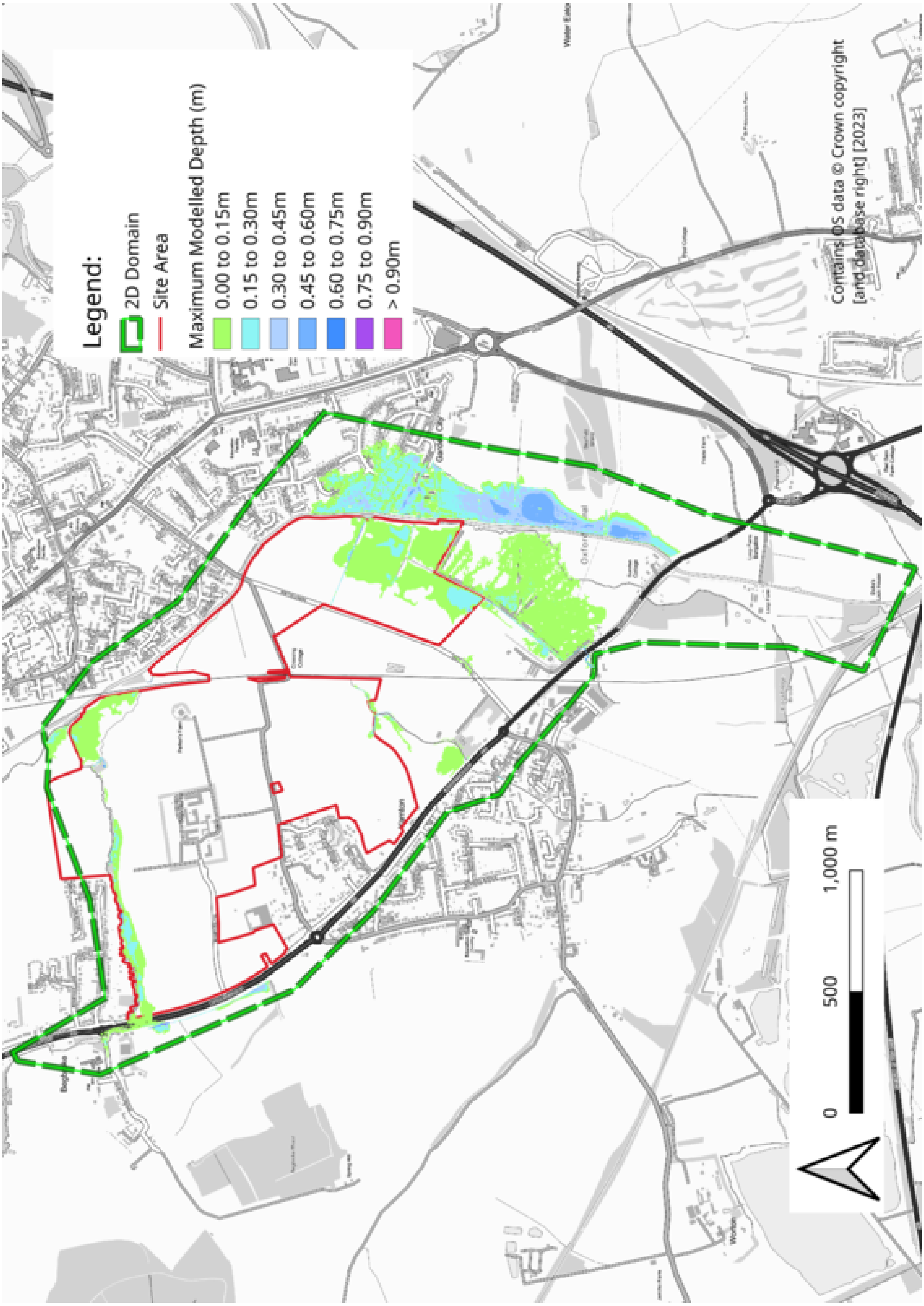

Figure 5.2: Maximum modelled depth in the 1% AEP event, 11 hour storm duration

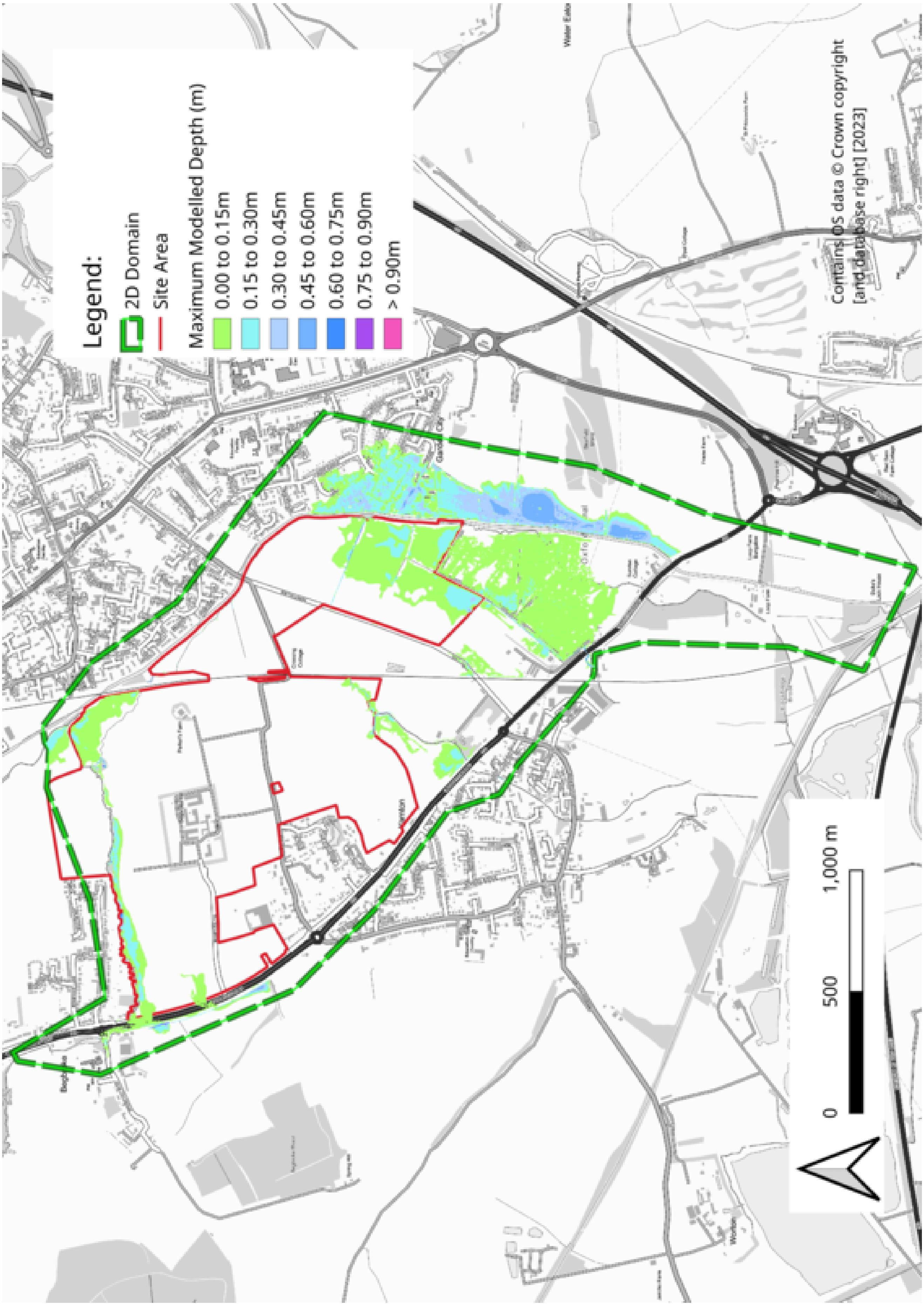

Figure 5.3: Maximum modelled depth in the 1% AEP event plus 26% allowance for climate change, 11 hour storm duration

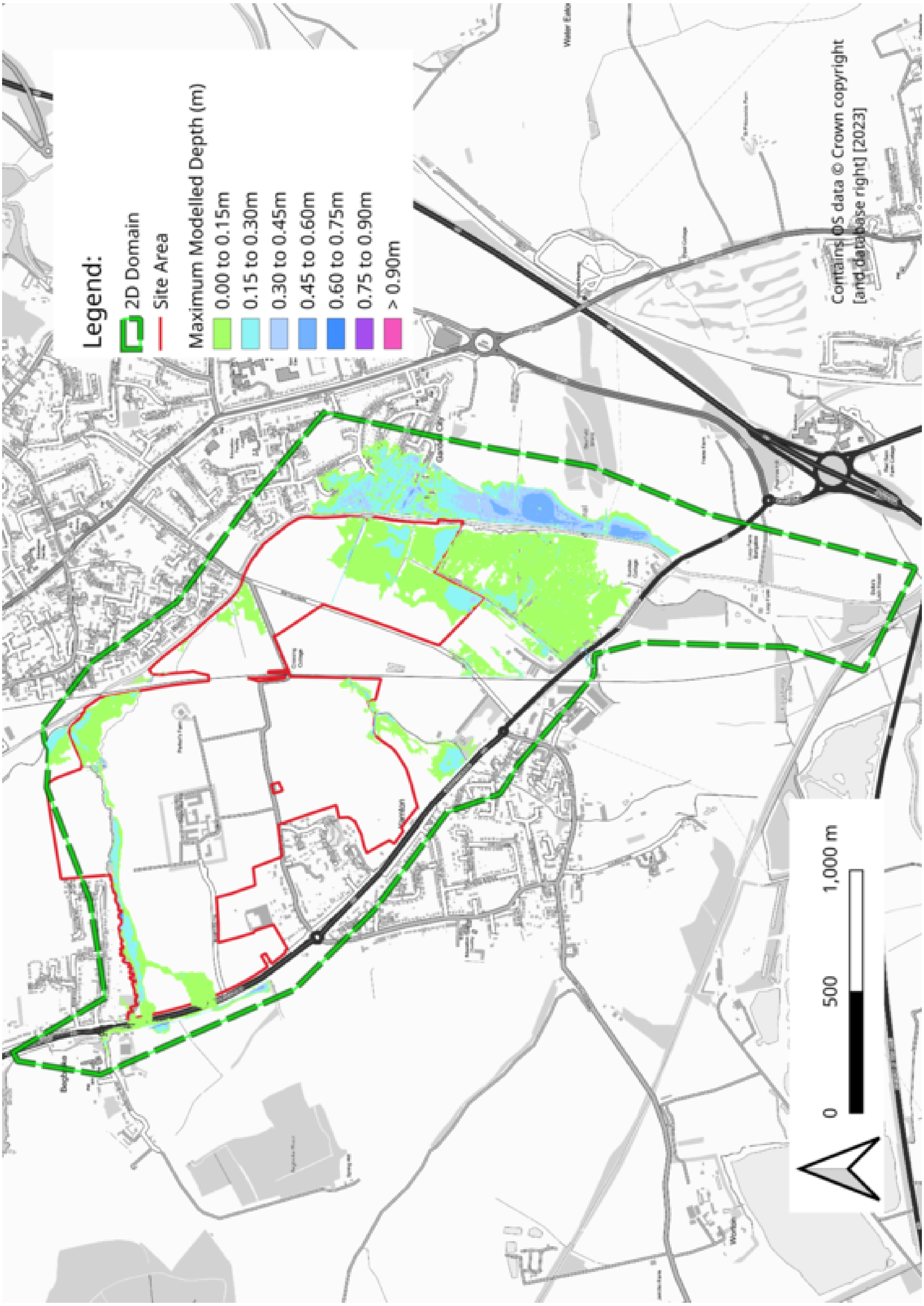

Figure 5.4: Maximum modelled depth in the 1% AEP event plus 41% allowance for climate change, 11 hour storm duration

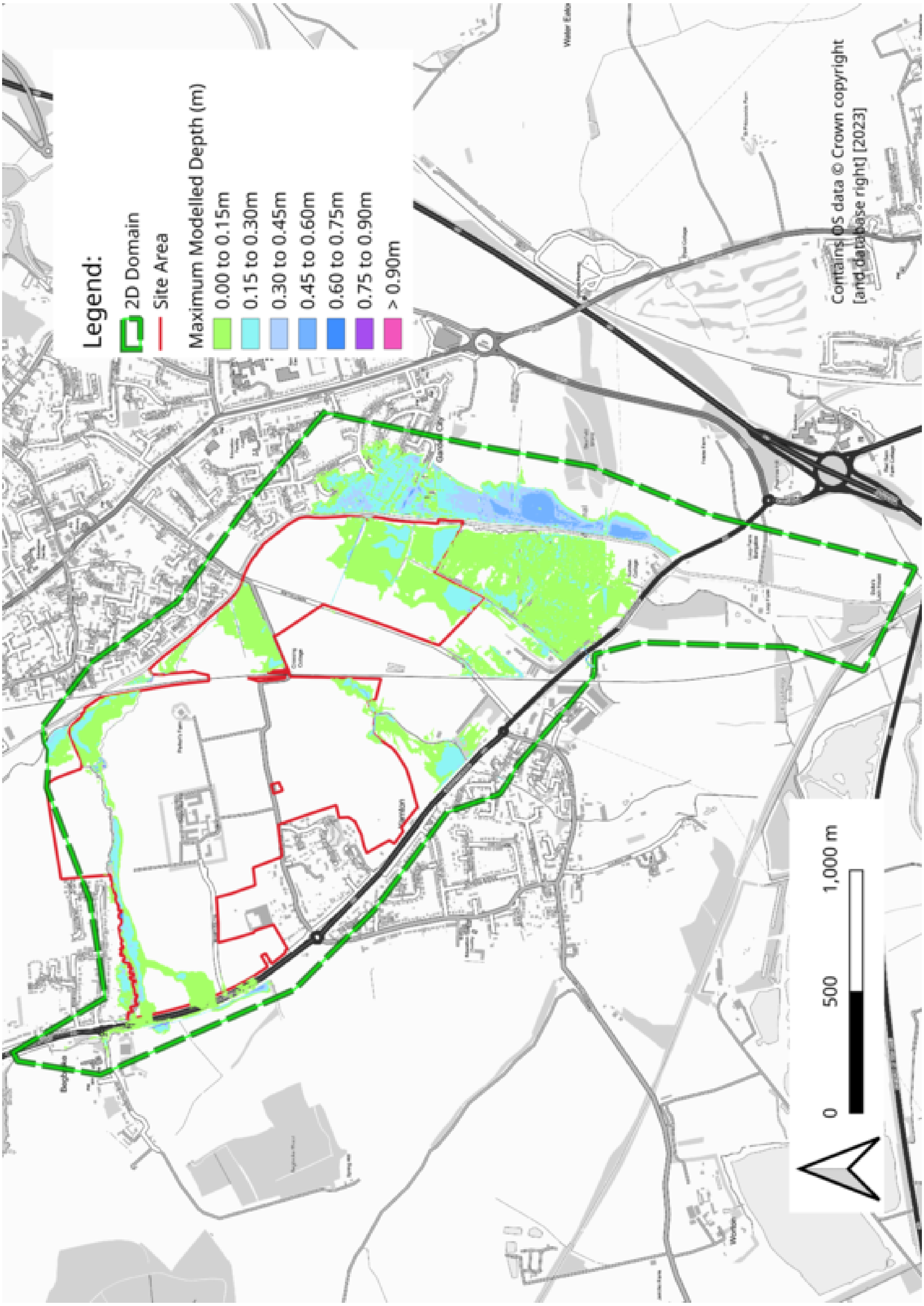

Figure 5.5: *Maximum modelled depth in the 0.1% AEP event, 11 hour storm duration*

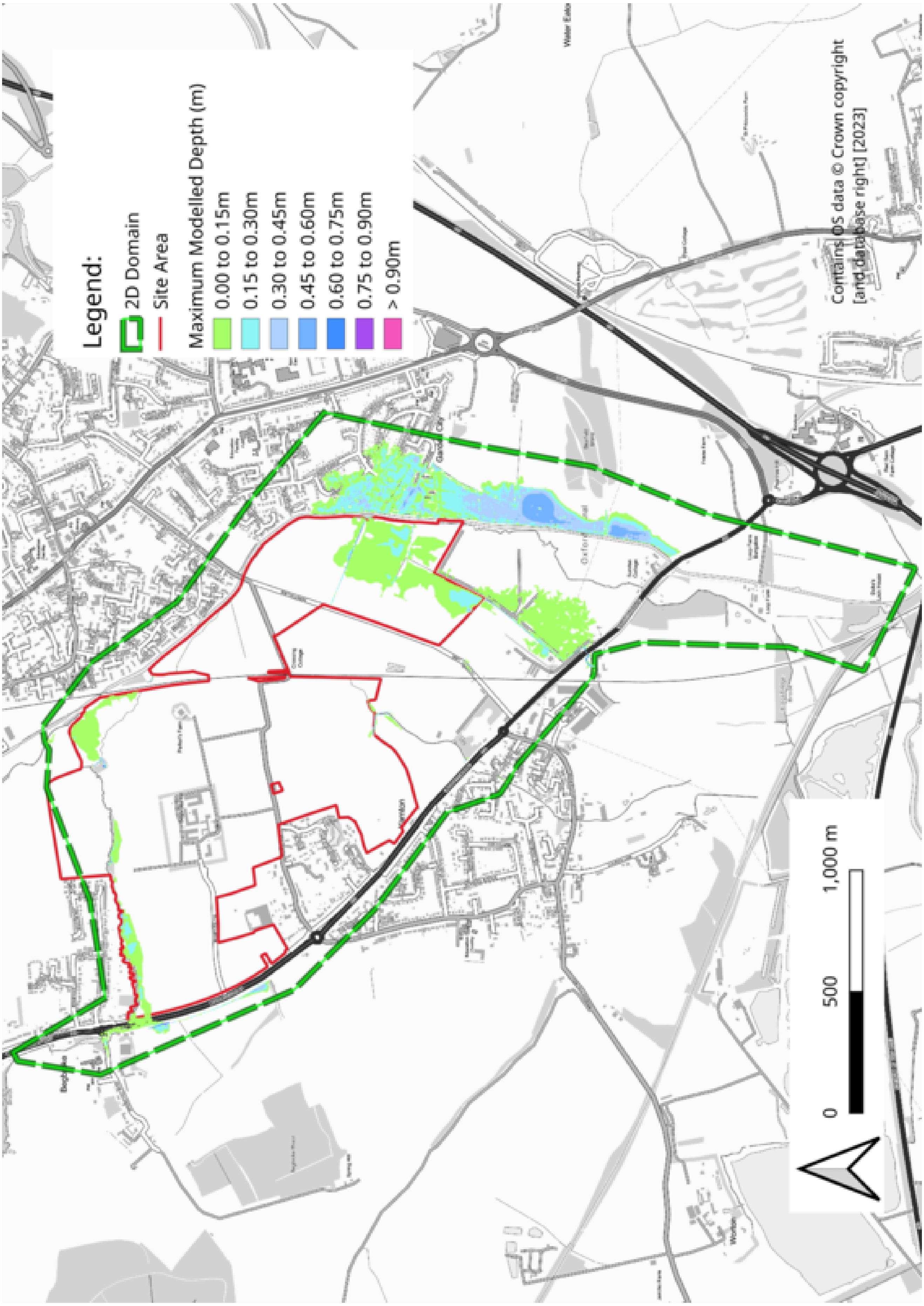

Figure 5.6: *Maximum modelled depth in the 3.33% AEP event, 3.5 hours storm duration*

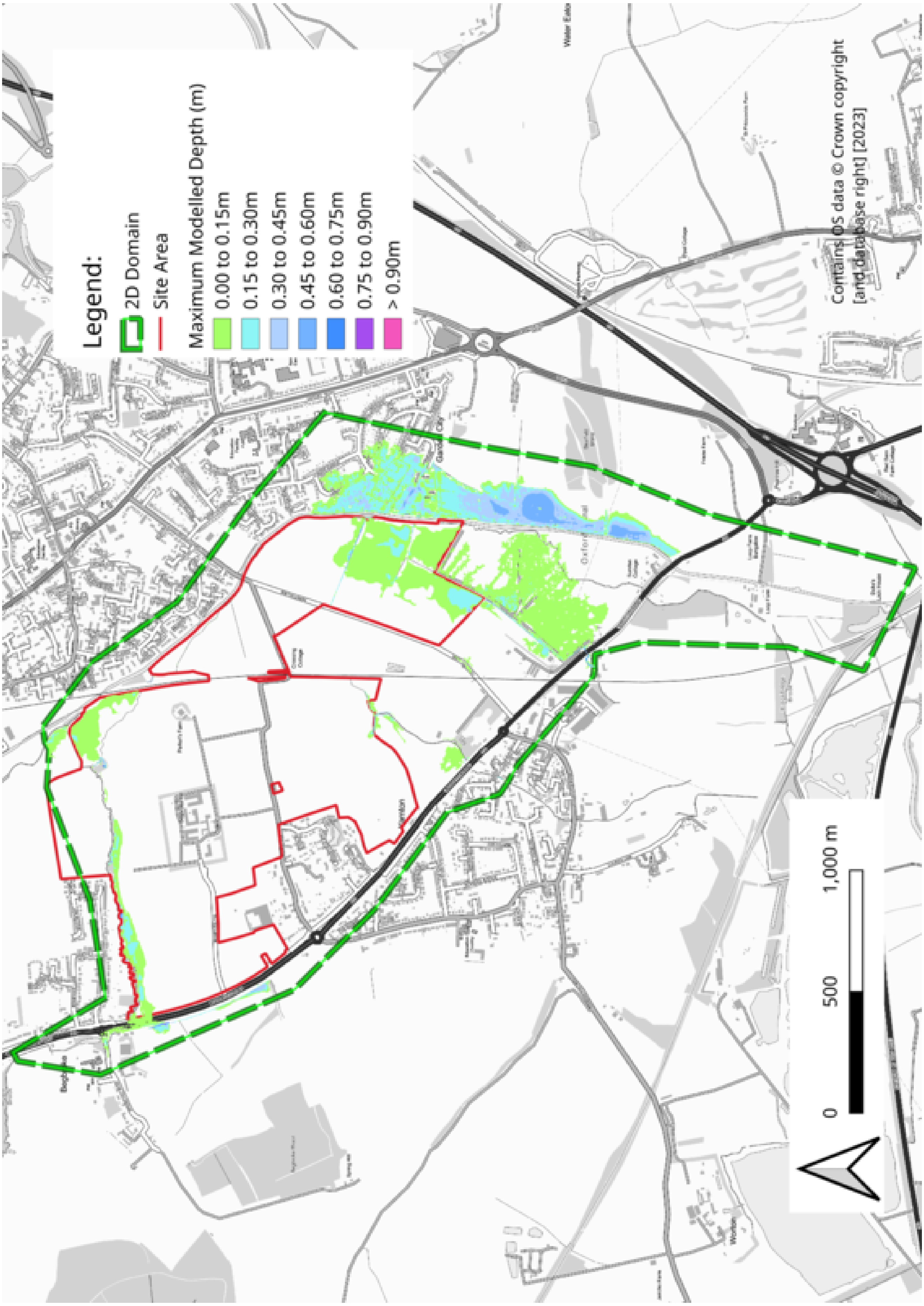

Figure 5.7: Maximum modelled depth in the 1% AEP event, 3.5 hours storm duration

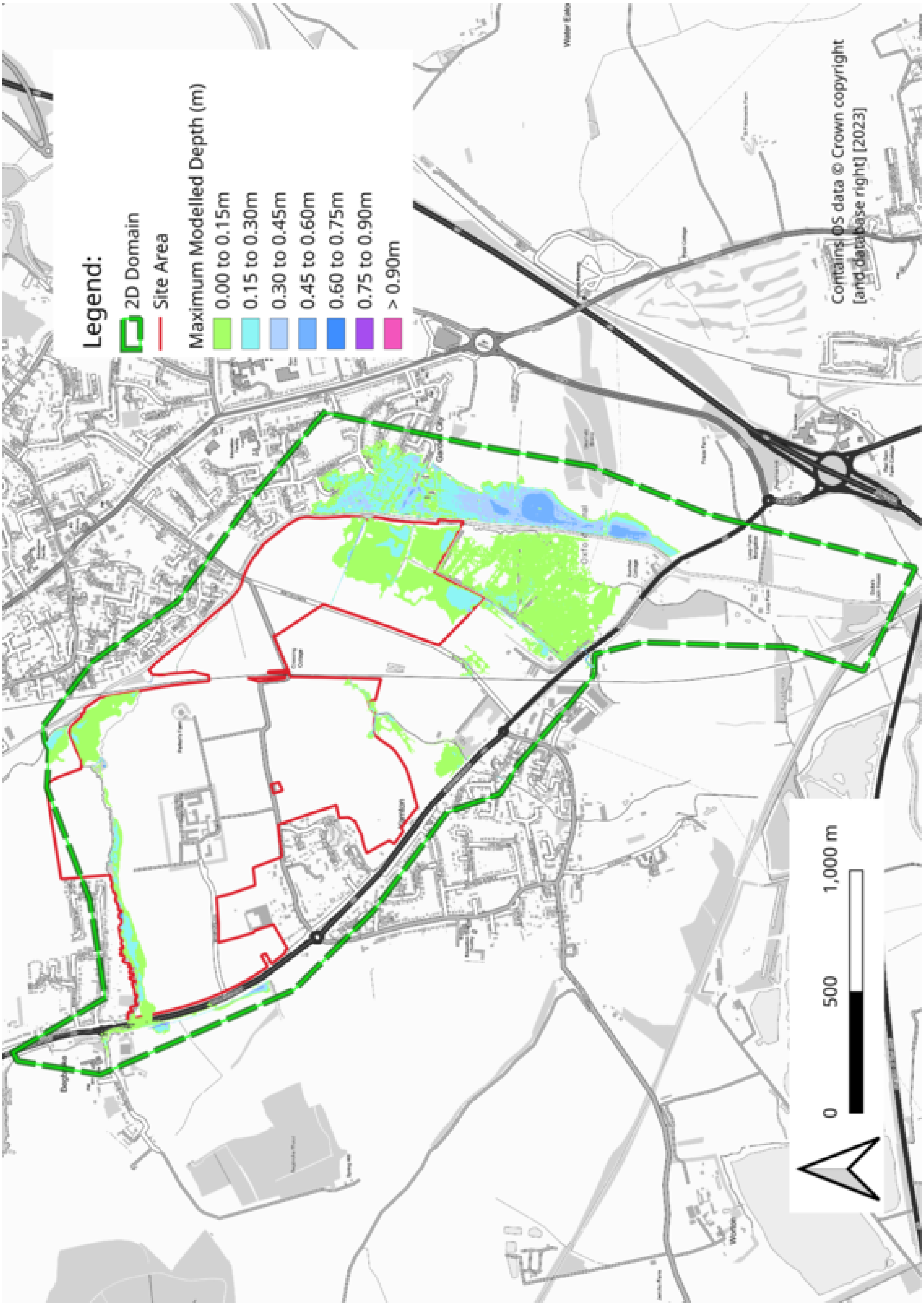

Figure 5.8: Maximum modelled depth in the 1% AEP event plus 26% allowance for climate change, 3.5 hours storm duration

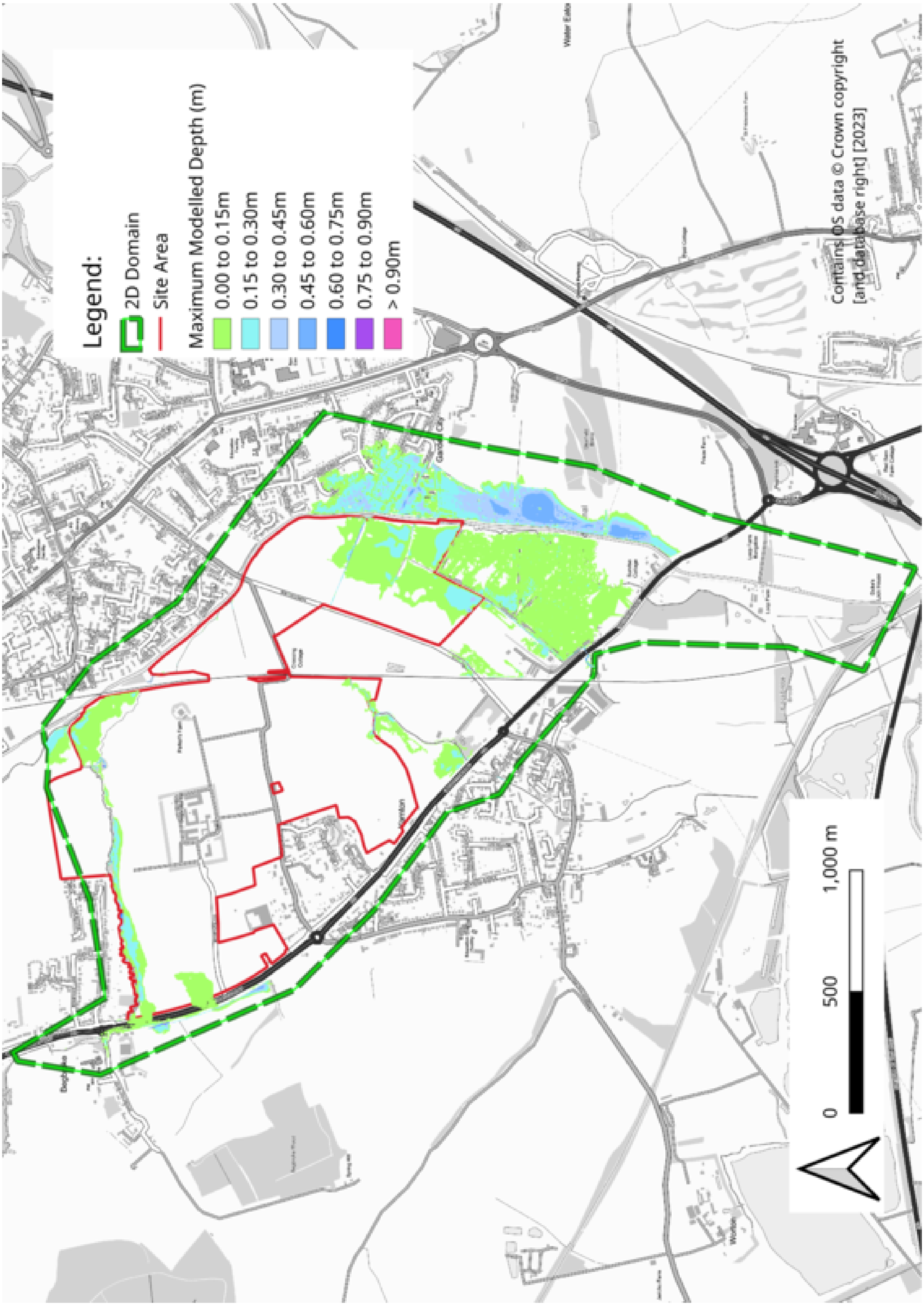

Figure 5.9: *Maximum modelled depth in the 1% AEP event plus 41% allowance for climate change, 3.5 hours storm duration*

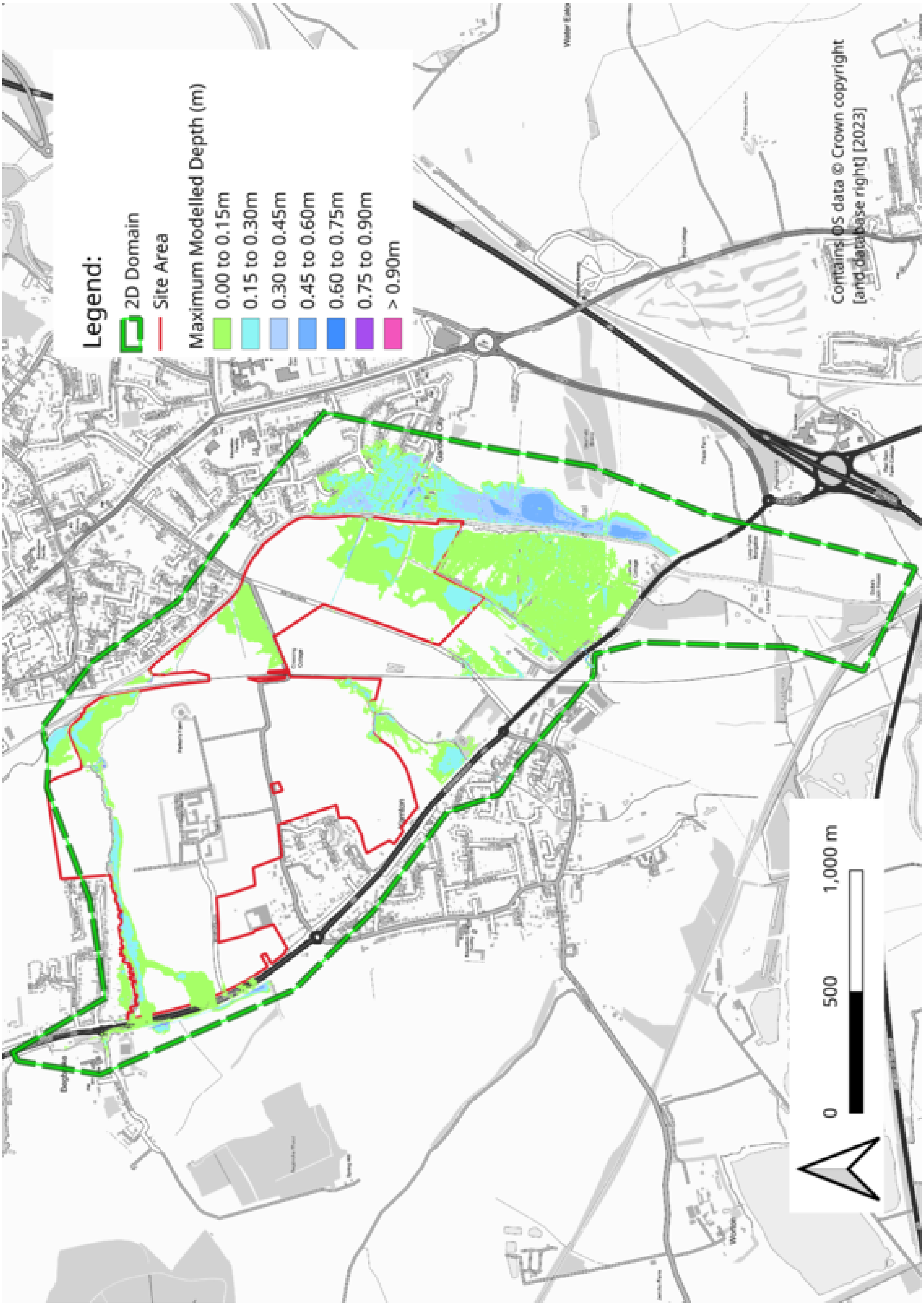

Figure 5.10: *Maximum modelled depth in the 0.1% AEP event, 3.5 hours storm duration*

5.2 Sensitivity Analysis

Three sensitivity tests have been undertaken.

A. Increase and decrease the roughness of the channel and land surfaces by 20%. The sensitivity test helps to quantify the impact of the uncertainty in the selection of roughness values on model results.

B. The downstream boundary conditions on the Eastern Drainage Ditches and the Southern Drainage Ditch have been sensitivity tested by doubling and halving the slope in these boundaries. They are currently modelled using HQ boundaries in the 2D domain on the basis they are located sufficiently downstream of the site to simply remove flow from the model without impacting results within the area of interest. These sensitivity tests quantify whether this assumption is reasonable.

C. The pound level upstream of Duke's Lock has been reduced by 0.1m. In the baseline case, the pound level has been modelled 0.1m higher than the maintained pound level due to a lack of information about the offtake structure at Duke's Lock. This sensitivity test reduces the pound level.

All the sensitivity tests have been undertaken using the 1% AEP design event without an allowance for climate change.

Increase or Decrease in Model Roughness

The results of changing the model's hydraulic roughness coefficients are shown in figures 5.11 and 5.12. The model is relatively insensitive to changes in roughness. Reducing roughness values results in a general reduction in flood extent, whilst increasing roughness values results in a general increase in flood extents. This is to be expected.

The greatest variation in flood extent occurs in area surrounding the Eastern Drainage Ditches and near to the solar farm, some of which falls outside of the site boundary. As ground levels are relatively flat, it is expected that the small changes in water level result in extension or contraction of the extent.

There is limited change to the flood extent around the Rowel Brook North, although it should be noted that increasing the roughness value does result in the ditch to the west of Woodstock Road beginning exceed its capacity.

Downstream Boundary Variation

The results of changing the assumed downstream boundary slopes of the eastern and southern drainage ditches are shown in figures 5.13 and 5.14. Variation in the slope of the HQ boundaries demonstrates that they are sufficiently far downstream to have no impact on-site.

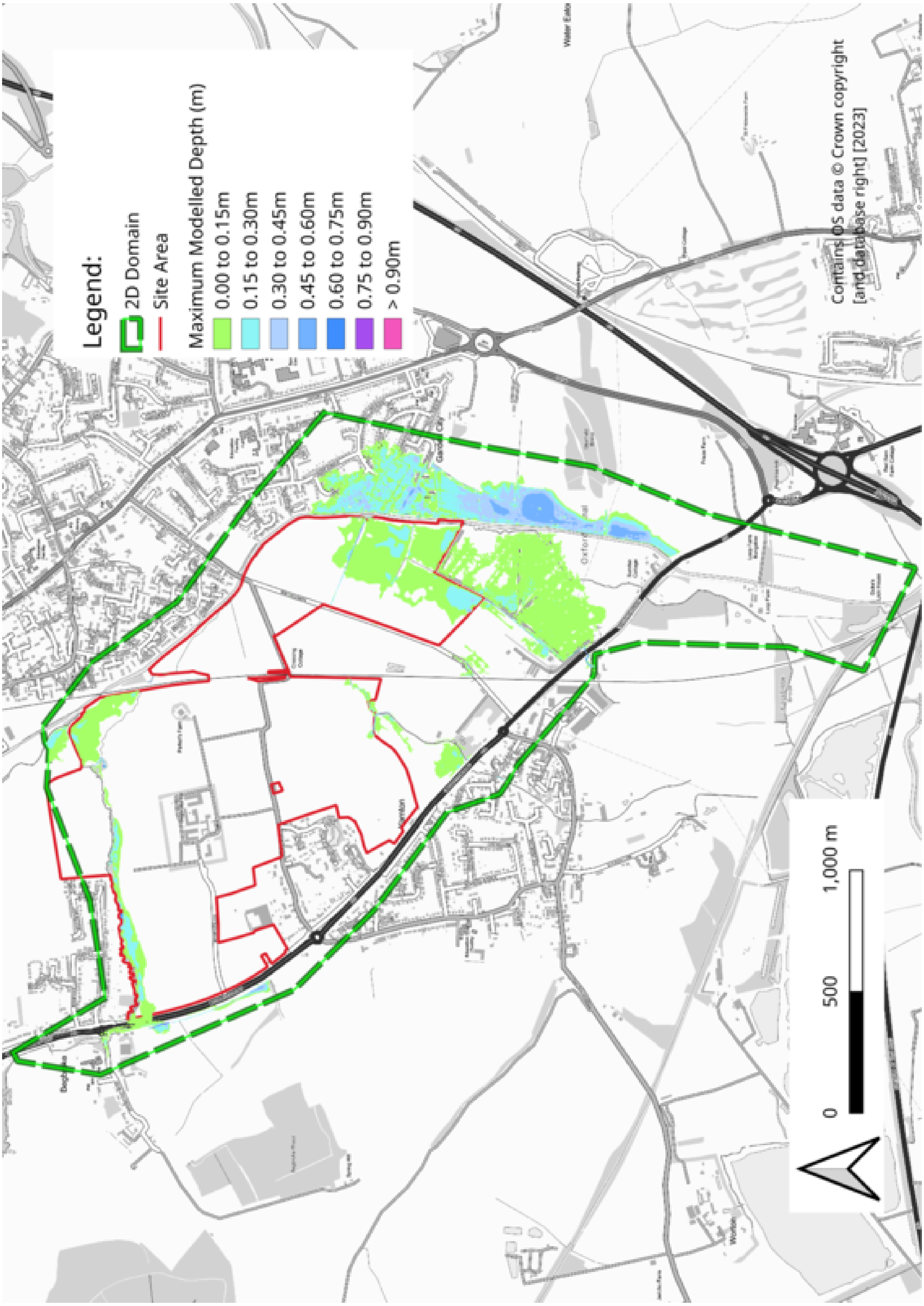

Figure 5.11: Maximum modelled depth in the 1% AEP event, 11 hour storm duration, 20% increase in roughness

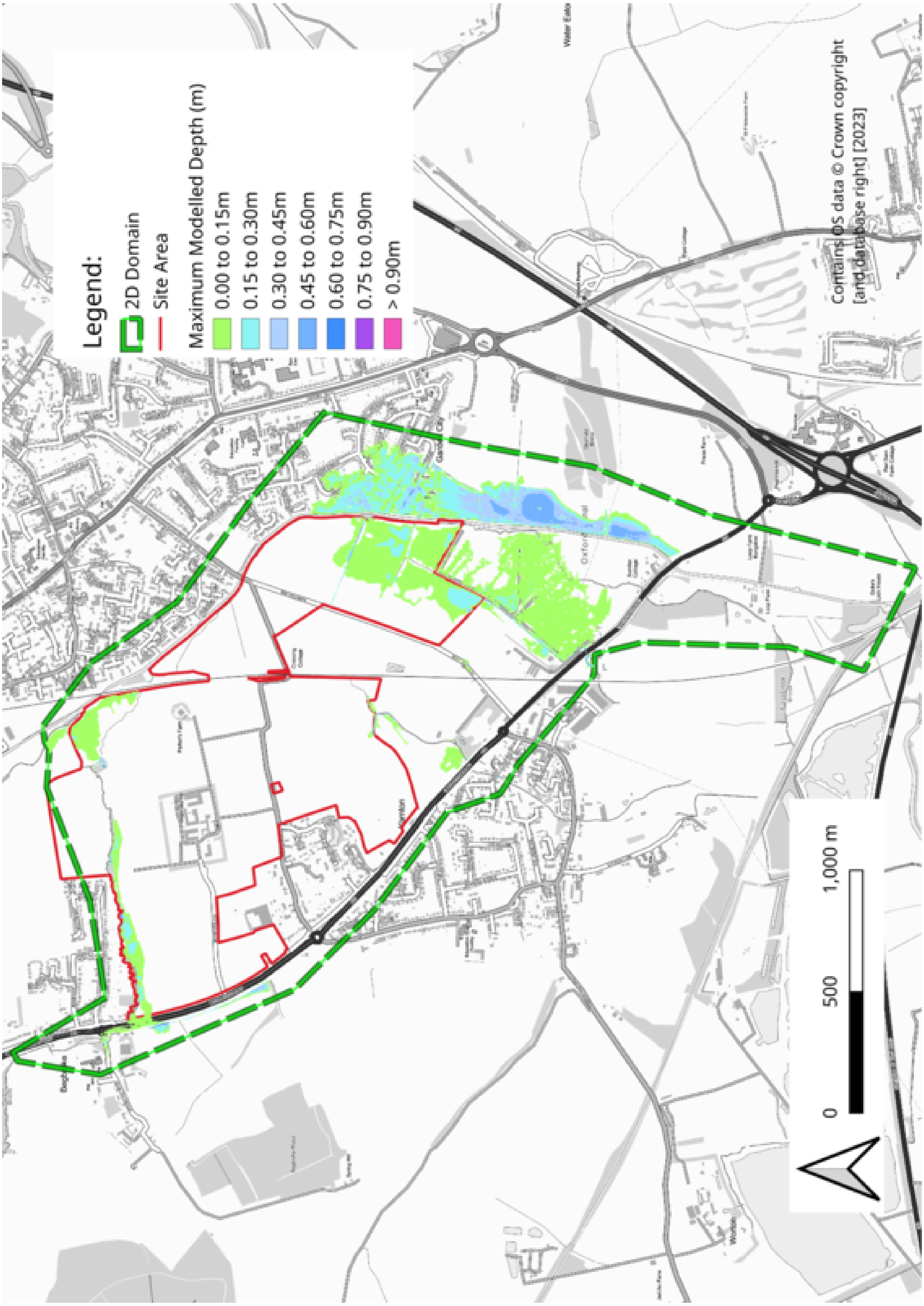

Figure 5.12: *Maximum modelled depth in the 1% AEP event, 11 hour storm duration, 20% reduction in roughness*

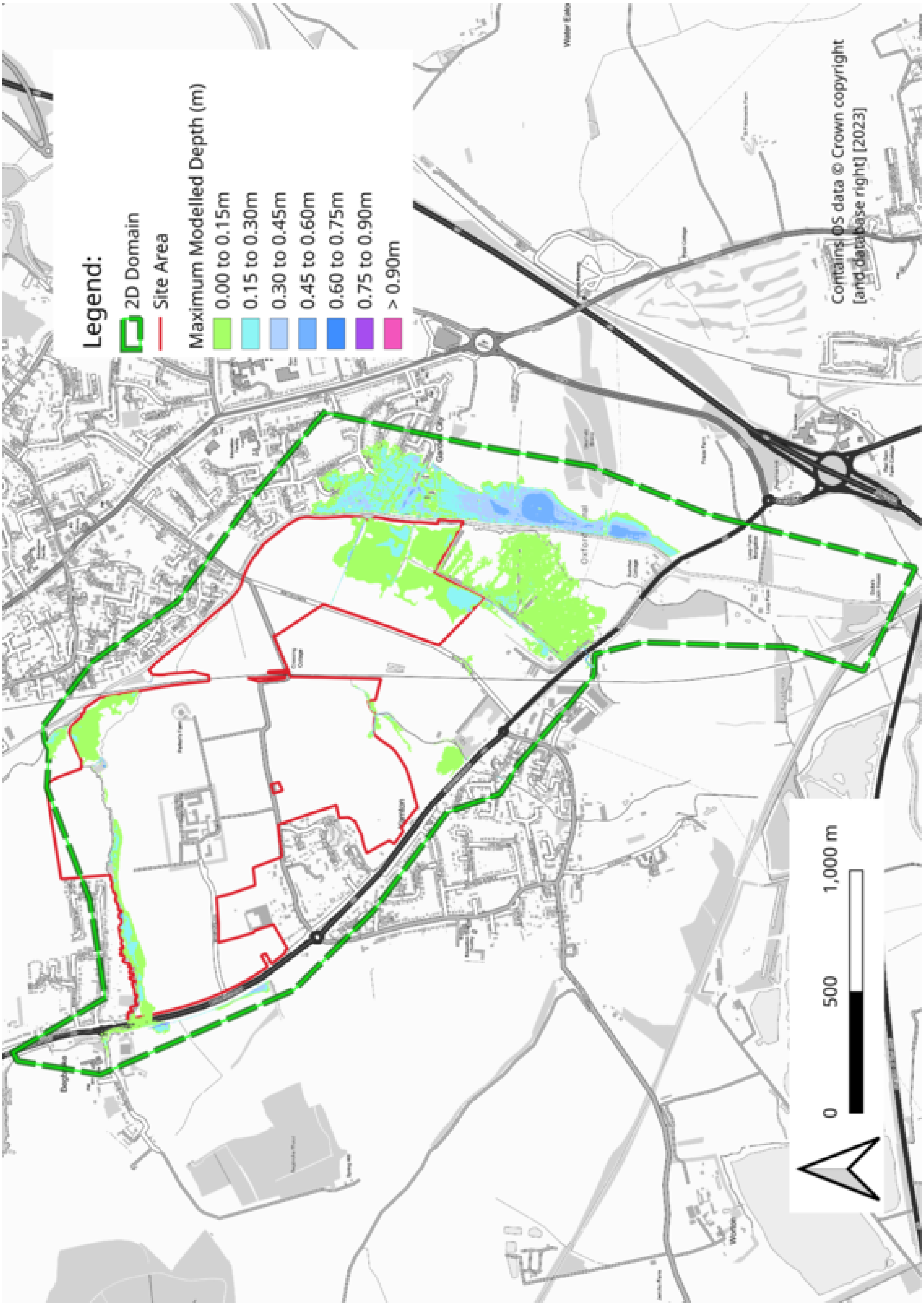

Figure 5.13: *Maximum modelled depth in the 1% AEP event, 11 hour storm duration, HQ boundary gradient doubled to 0.02*

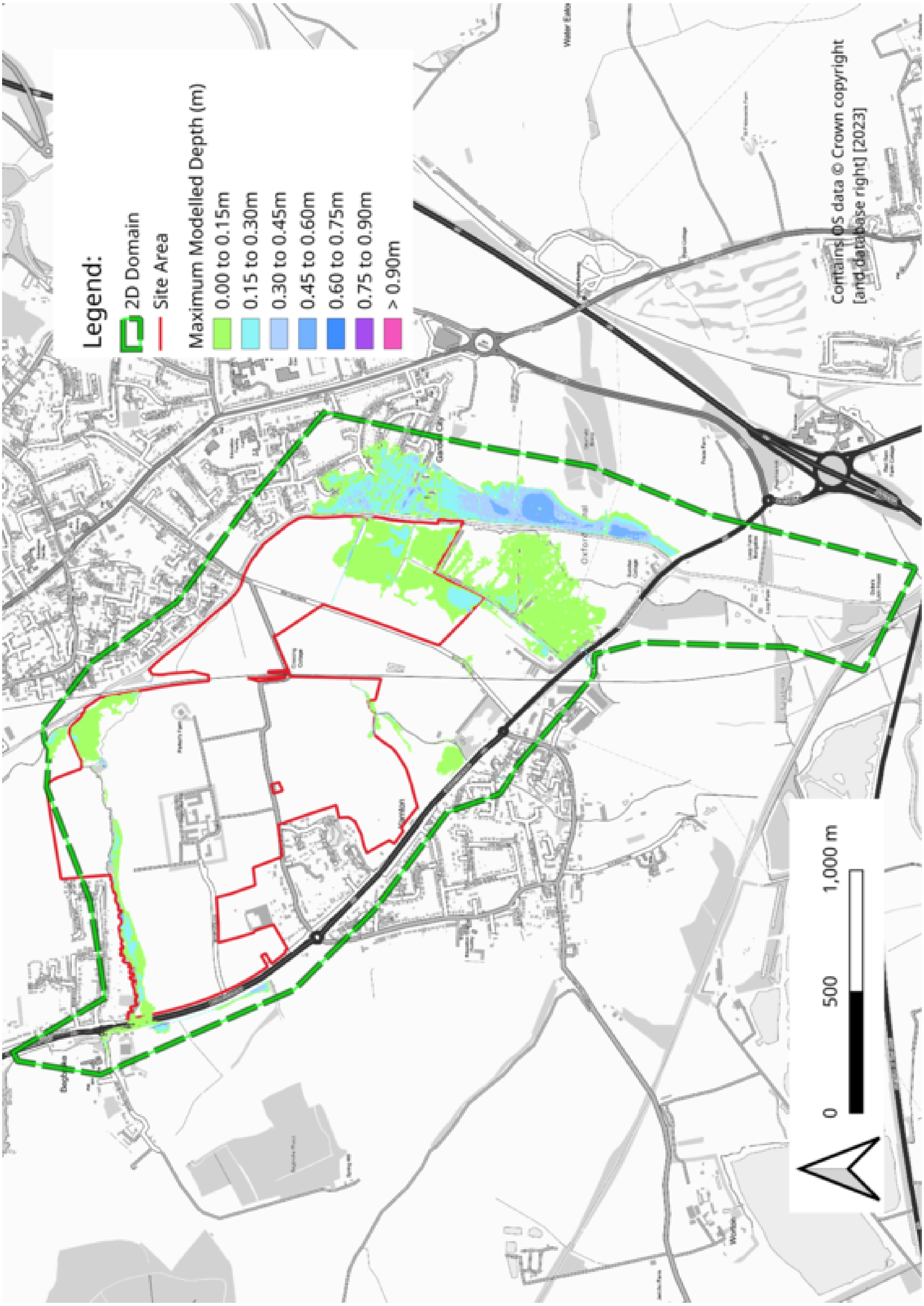

Figure 5.14: Maximum modelled depth in the 1% AEP event, 11 hour storm duration, HQ boundary gradient halved to 0.005

Canal Pound Level Variation

The result of changing the assumption made about the downstream pound level at Dukes Lock on the Oxford canal is shown in figure 5.15. Variation in the canal pound level is shown to have negligible impact on-site. There is some change in water level within the bypass channel at Kidlington Green Lock, but this is extremely localised and has no impact on flood extent.

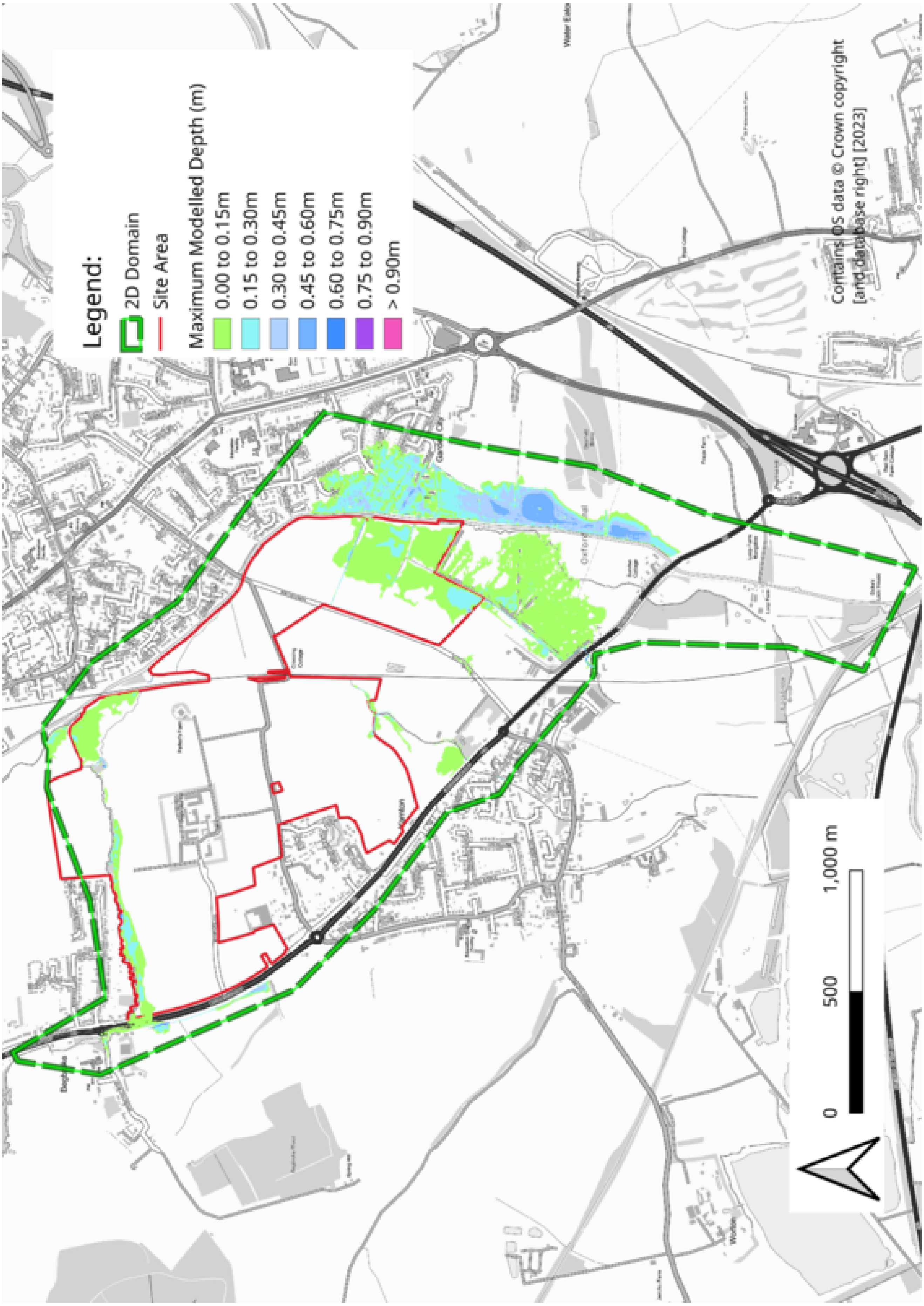

Figure 5.15: Maximum modelled depth in the 1% AEP event, 11 hour storm duration

6. Proposed Swale

6.1 Overview

The model shows flooding to the northwest of the site in the 0.1% AEP event and 1% AEP event with 41% climate change allowance. The water comes from the Begbroke Hill area, west of Woodstock Road, flowing across the road into the site area where buildings are proposed (figures 5.4 and 5.5). This flooding then drains into Rowel Brook North floodplain.

Mitigation will be required to ensure that the new development does not flood during these events. The mitigation strategy recommended in this report is to construct a swale to the west of the site area at risk, running parallel to the road.

6.2 Model

The swale has been modelled in the 1D, utilising the same techniques as described in section 4.3. It's location is illustrated in figure 6.1.

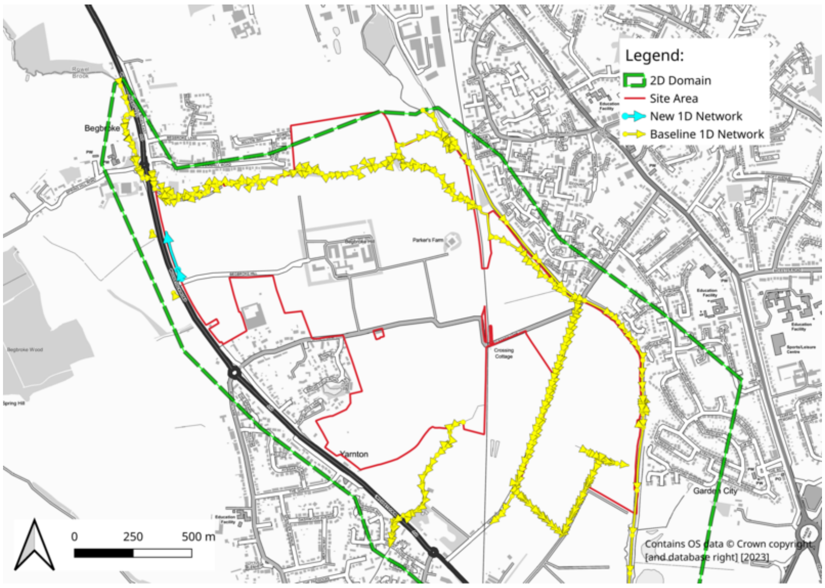

Figure 6.1: *Location of Swale in the North-west of the site*

The geometry of the swale has a base width of 5 m, a top width of 7 m, and is 0.5 m deep. This forms a shallow channel with 1:2 sides, extending for 207.7 m. The channel geometry is deliberately large so that the swale acts in part as flood storage as well as conveying the flow around the site.

The topography around the swale's east and north banks has been altered to form a 'wall', shown in figure 6.2. This ensures that all of the flow across the Woodstock Road is captured by the swale in all of the design flood events where the swale operates. In practice, this structure does not need to be implemented as a wall and could be a low embankment or any other structure impervious to flood water east of the swale to an average height of approximately 0.3 m.

The swale has been designed to attenuate the flood water as well as convey it to the north. This ensures that the travel time for water moving through the swale is similar to that of water that does not cross the Woodstock Road and that flood risk is therefore not increased in the Rowel Brook due to providing a more direct flow path.

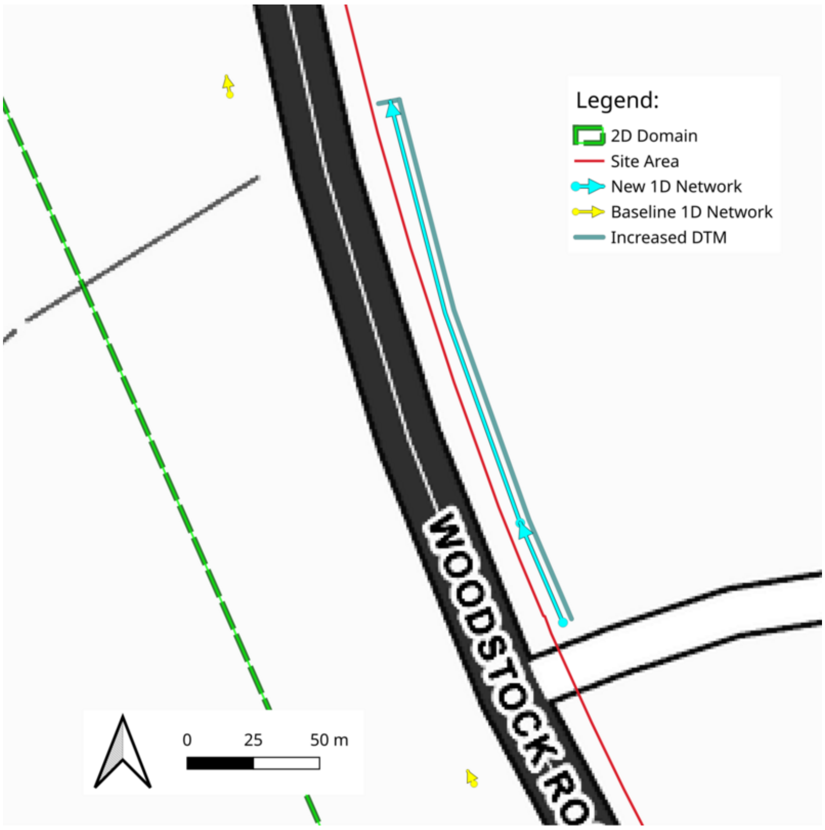

Figure 6.2: *Location of where the DTM has been increased to form a natural wall*

6.3 Results

Maximum Depth

Figures 6.3 and 6.4 show the maximum depth results when the swale is included for the 1% AEP event with 41% allowance for climate change and the 0.1% AEP event, 11-hour storm duration.

The maximum flood depth results illustrate that flooding is situated around the northern edge of the field, in the Rowel Brook North's floodplain. The maps show there is still build-up on Woodstock Road, yet it is not spilling over into the development area, demonstrating that the swale is a functional flood mitigation option.

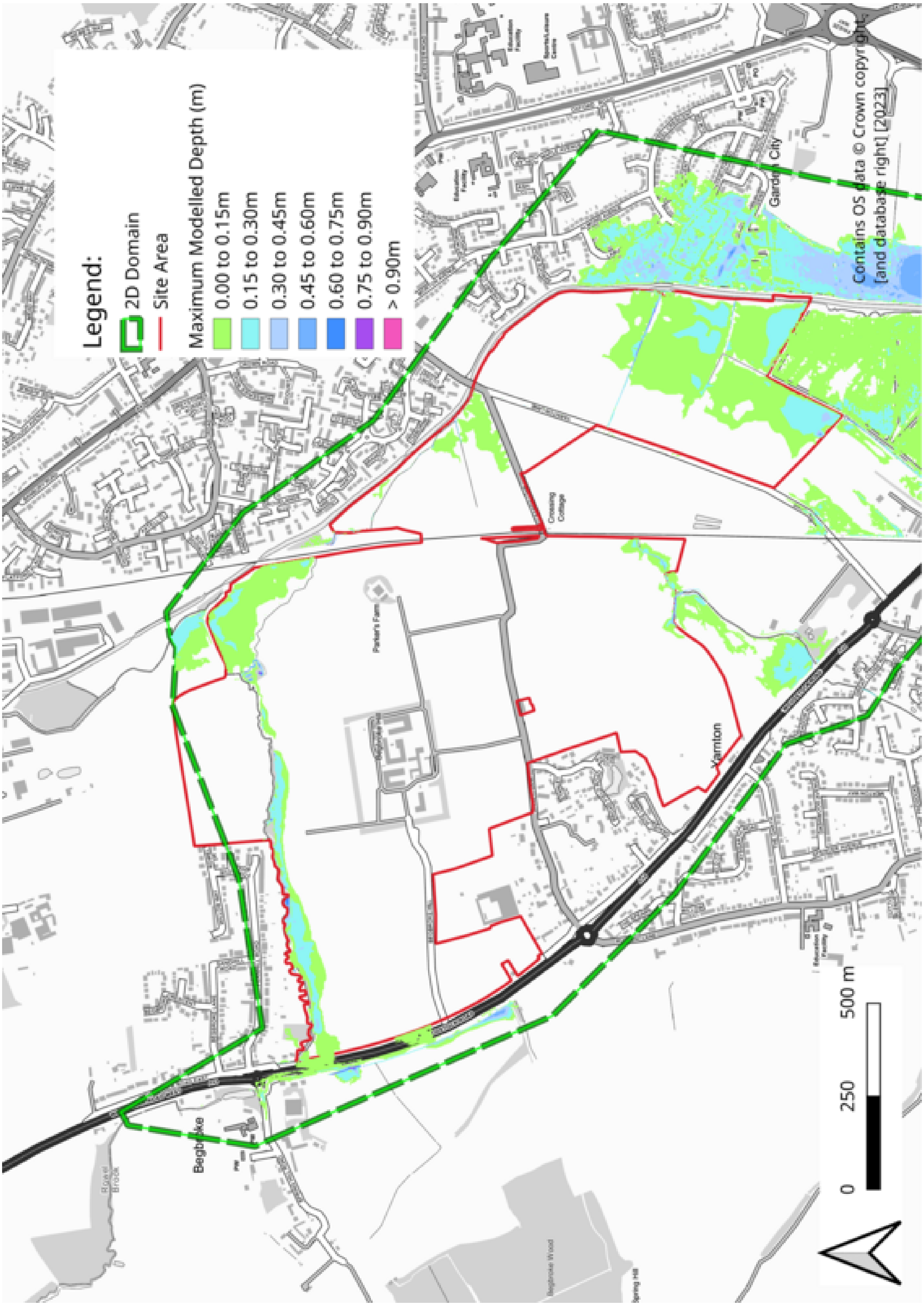

Figure 6.3: *Maximum modelled depth with mitigation in the North-west of the site in the 1% AEP event plus 41% allowance for climate change, 11 hour storm duration*

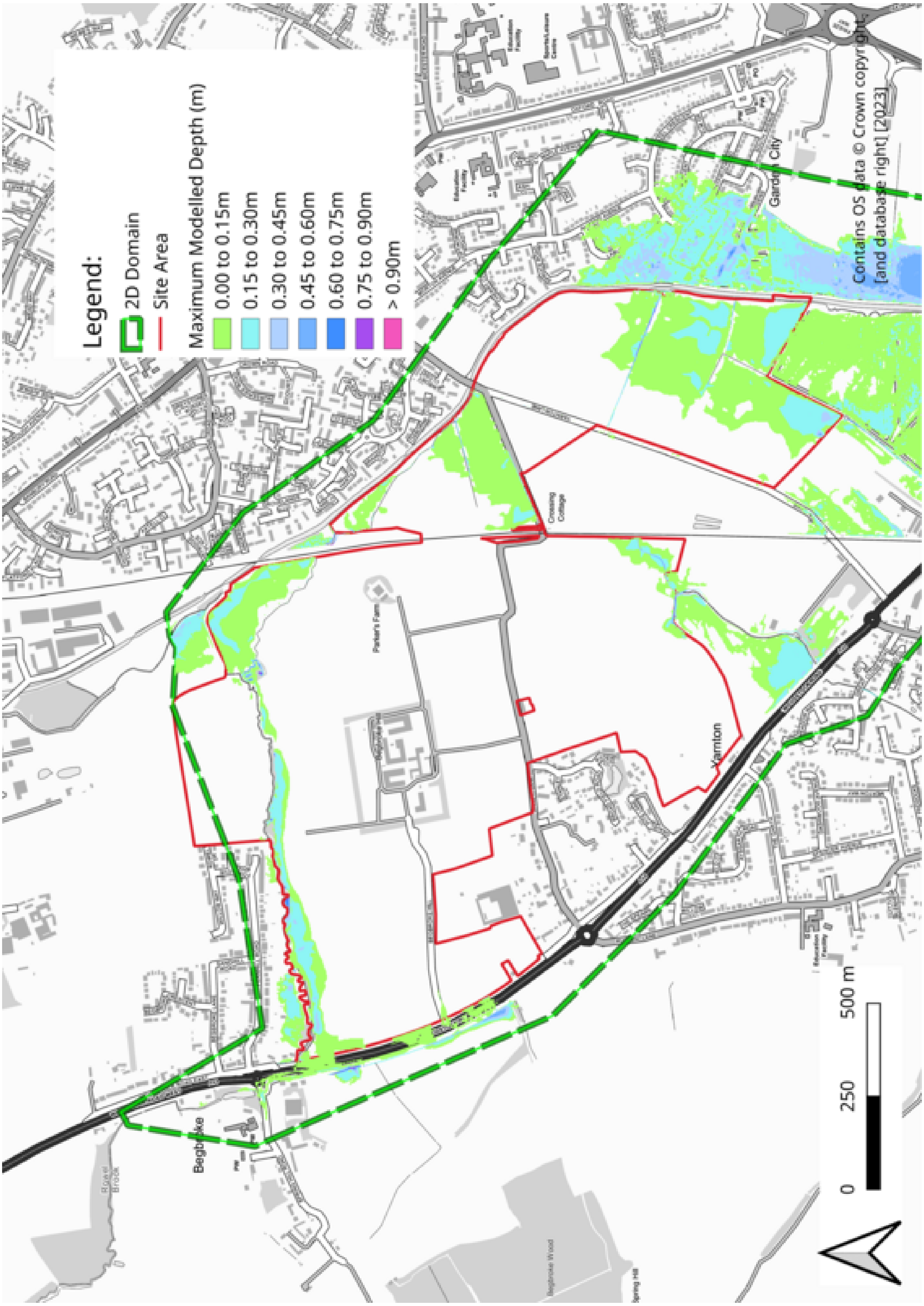

Figure 6.4: *Maximum modelled depth with mitigation in the North-west of the site in the 0.1% AEP event, 11 hour storm duration*

Flood Level Differences

Figures 6.5 and 6.6 show the difference in maximum flood level between the mitigated swale scenario and the baseline model, for the 1% AEP event plus 41% allowance for climate change and the 0.1% AEP event, 11 hour storm duration. Where there is zero or negligible (<5 mm) change in the maximum flood level, the results have been blanked out. For an increase in maximum flood level the results are shades of orange/red and where there has been a decrease the results are green/blue.

Figure 6.5 demonstrates that the construction of the Swale prevents the proposed development from flooding and causes no increased flood risk anywhere else, for the 1% AEP plus 41% climate change allowance event. The 0.1% AEP event (figure 6.6) has a increase in maximum flood level just north of the swale where the water moving through the swale is redirected north toward the Rowel Brook floodplain. The dark red conveys there is new flood water and the orange conveys that the new flood water has caused an increase in maximum flood level of 0.005–0.100 m at the edge of the floodplain. This increased flood risk is entirely contained within the site boundaries and does not impact on any part of the proposed development. The model shows no increased flood risk to any third party.

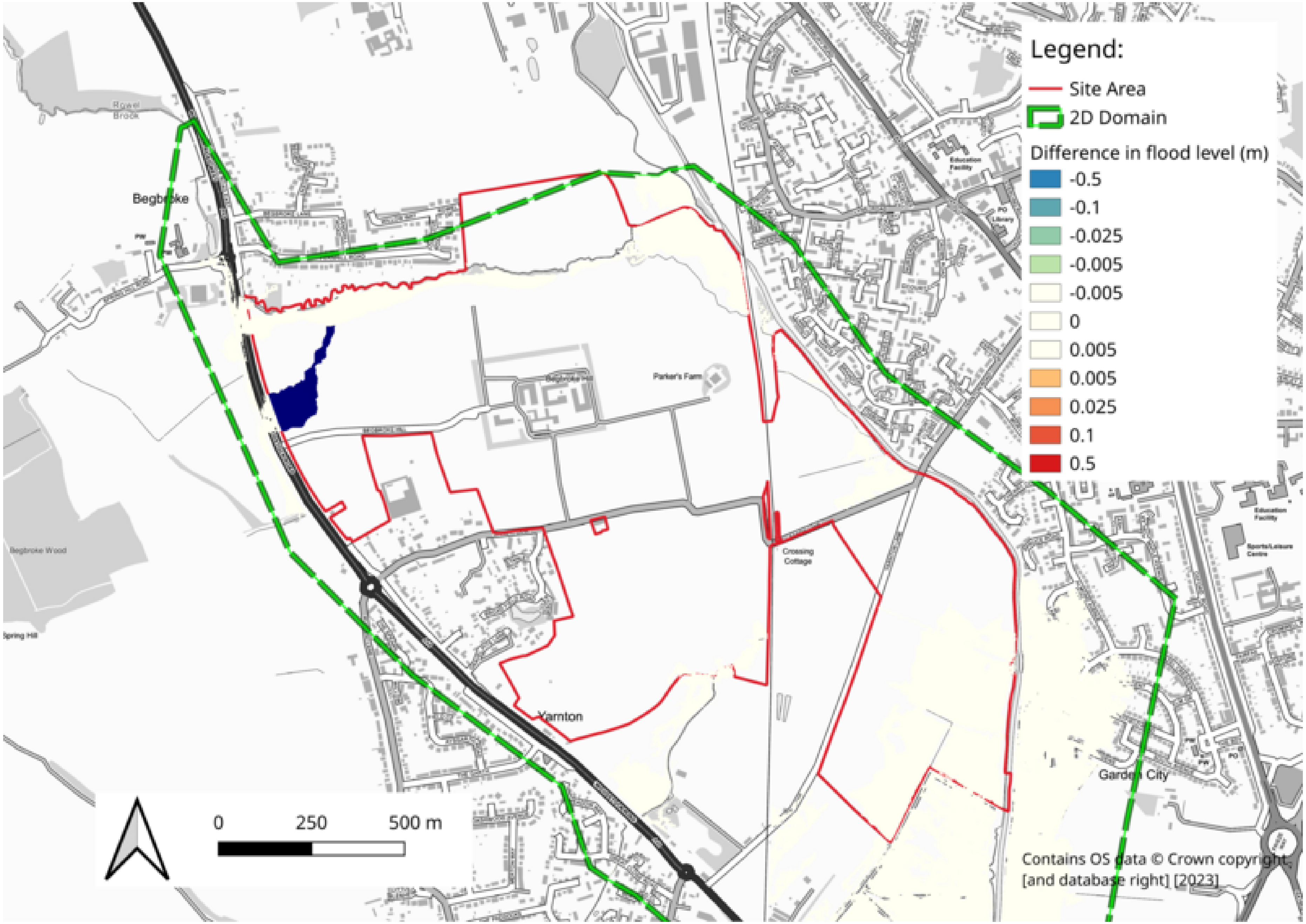

Figure 6.5: *Difference in flood level between the baseline model and the North-west mitigation scenario in the 1% AEP event plus 41% allowance for climate change, 11 hour storm duration*

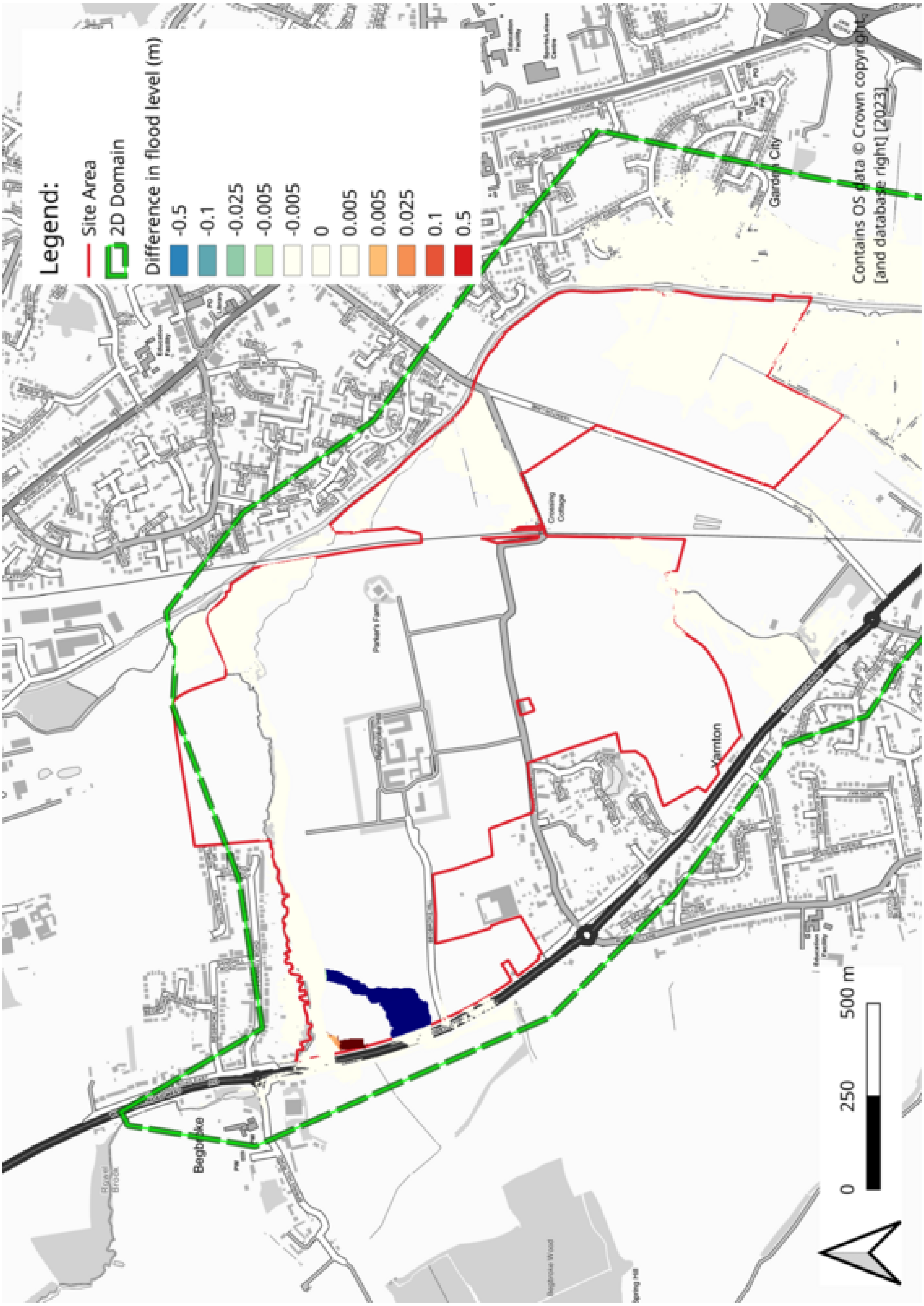

Figure 6.6: Difference in flood level between the baseline model and the North-west mitigation scenario in the 0.1% AEP event, 11 hour storm duration

RECOMMENDATIONS

7. Conclusions

Edenvale Young Associates were commissioned to undertake hydraulic modelling adjacent to the existing Begbroke Science Park, Oxfordshire. The following tasks have been undertaken:

- A baseline ESTRY-TUFLOW model has been constructed using detailed topographic survey and a bespoke hydrological analysis has been undertaken.
- The model has been run for a range of design events
- Sensitivity testing has been undertaken to assess the impact of key assumptions on the results

The results show flooding to the site of interest, with the majority of out of bank flooding occurring on the eastern side of the site close to the Oxford Canal and Eastern Drainage Ditches. Where proposed development would intersect with the flood extents of the 1% AEP events with climate change allowance it is recommended that such development is relocated, or mitigation work is undertaken to ensure that the development is not at risk and no third-party impacts are caused.

A small area of flood risk to the proposed development in the 1% AEP with 41% climate change allowance and 0.1% AEP flood events has been identified in the northwest corner of the site. The modelling has been used to inform the outline design of a swale which has been shown to be an effective flood mitigation measure for these events that does not cause any third-party impact.

APPENDIX

A. Flood Estimation Report

Flood Estimation Report Template

Template: LIT 65087 Published: 29/12/2022

Audience: Environment Agency

Description: This report template is a supporting document to the Environment Agency's Flood Estimation Guidelines (LIT 11832). It provides a record of the hydrological context, the method statement, the calculations, the decisions made, and the results of flood estimation. This document can be used for one site or multiple sites.

Guidance notes to help you complete this template are available separately.

Contents

Approval

Revision stage	Analyst:	Approved by:	Amendments	Date
Method statement	Sara Liguori			03/02/2023
Calculations - Revision 1				
Calculations - Revision 2				

Abbreviations

Abbreviation	Short for
AEP	annual exceedance probability
AMAX	Annual Maximum
AREA	Catchment area (km2)
BFI	Base Flow Index
BFIHOST19	Base Flow Index derived using the HOST soil classification, revised in 2019
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
GEV	Generalised Extreme Value
GLO	Generalised Logistic
HOST	Hydrology of Soil Types
IF	Impervious Fraction
IRF	Impervious Runoff Factor
LF	Low flow statistics (flow duration curve)
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
ReFH2	Revitalised Flood Hydrograph 2 method
SAAR	Standard Average Annual Rainfall (mm)
Tp	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP	Windows Frequency Analysis Package (software that can be used for FEH statistical method)

1. Summary of assessment

1.1 Summary

Catchment location:

Begbroke, including Rowel Brook, Thrupp ditch and Southern Drainage ditch, Oxfordshire

Purpose of study and complexity:

Routine hydrological assessment to estimate design hydrographs needed as input to the 1D-2D hydraulic model of the watercourses in the area of study.

Key catchment features:

The site of intereset is rural but the hydrological catchments of interest for the estimation of runoff to and from the site are more variously characterised. The overall contributing catchment downstream of the site, at the downstream hydraulic model extent, is moderately urbanised. All hydrological catchments of interest are classified as small.

Flooding mechanisms:

Fluvial and pluvial.

Gauged / ungauged:

Ungauged

Final choice of method:

Statistical peak flow estimates; hydrograph shapes from ReFH2

Key limitations / uncertainties in results:

Lack of data to inform analysis and verify results.

1.2 Flood frequencies

- The frequency of a flood can be quoted in terms of a return period, which is defined as the average time between years with at least one larger flood, or as an annual exceedance probability (AEP), which is the inverse of the return period.
- Return periods are output by the Flood Estimation Handbook (FEH) software and can be expressed more succinctly than AEP. However, AEP can be helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval.
- Results tables in this document contain both return period and AEP titles; both rows can be retained, or the relevant row can be retained and the other removed, depending on the requirement of the study.
- The table below is provided to enable quick conversion between return periods and annual exceedance probabilities.

AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1
AEP	0.5	0.2	0.1	0.05	0.033	0.02	0.013	0.01	0.005	0.001
Return period (yrs)	2	5	10	20	30	50	75	100	200	1,000

2. Method Statement

2.1 Requirements for flood estimates

Overview and Project Scope:

This document details the hydrological analysis undertaken to derive design peak flows and hydrographs for use in a 1D-2D hydraulic model of the Rowel Brook, Thrupp ditch and Southern drainage ditch at a site near Begbroke, Oxfordshire. The results of the hydraulic modelling will be used for the purpose of informing a flood risk assessment for a proposed development.

Design peak flow estimates and hydrographs will be derived for the following AEP (%) events: 3.33, 1, and 0.1. In addition, the following AEP (%) events have been considered for the purposes of this assessment: 50, 20, 10, 2, 0.5, and 0.2. The impact of climate change on flood risk will be assessed by applying climate change allowances to the 1%AEP flow estimates. The central (20%) and higher (41%) allowances for the 2080s epoch, as defined by current climate change guidance[1] for the Gloucestershire and Vale Management Catchment, will be considered for the purposes of the hydraulic modelling.

Design estimates will be derived as lumped inflows for the Rowel Brook, Thrupp ditch, and Southern drainage ditch at the site. The contribution of the intervening area at the d/s extent of the hydraulic model will be estimated from the overall catchment at this location. A map of the approximate site boundaries and contributing catchments as defined on the FEH Web is shown in Figure 1.

It is anticipated that the FEH catchments boundaries and contributing areas will be refined on the basis of the results of a Direct Rainfall Model (DRM) built for the area of interest. The DRM will provide information about flow paths in the area on the basis of the LiDAR DTM and known local features impacting on the topography and the hydrological connectivity in the area. It is also anticipated that the distribution of runoff estimated for the intervening area will be made in accordance with the indication of relevant flow paths as shown by the results of the direct rainfall model.

It should be noted that the hydrological analysis detailed in this document is based on the assumption that the Oxford Canal is a hydrological barrier and does not require an inflow. However, this assumption might be re-examined and appropriate adjustments made should the direct raiinfall modelling indicate that a significant runoff contribution is to be taken into account for the purposes of the hydraulic model. It should also be noted that details on the DRM model build and

[1] Environment Agency. Flood risk assessments: climate change allowances. Last Updated May 2022 https://environment.data.gov.uk/hydrology/climate-change-allowances/river-flow

analysis of DRM results are outside the scope of this document and will be covered elsewhere.

2.2 The Catchment

Maps:

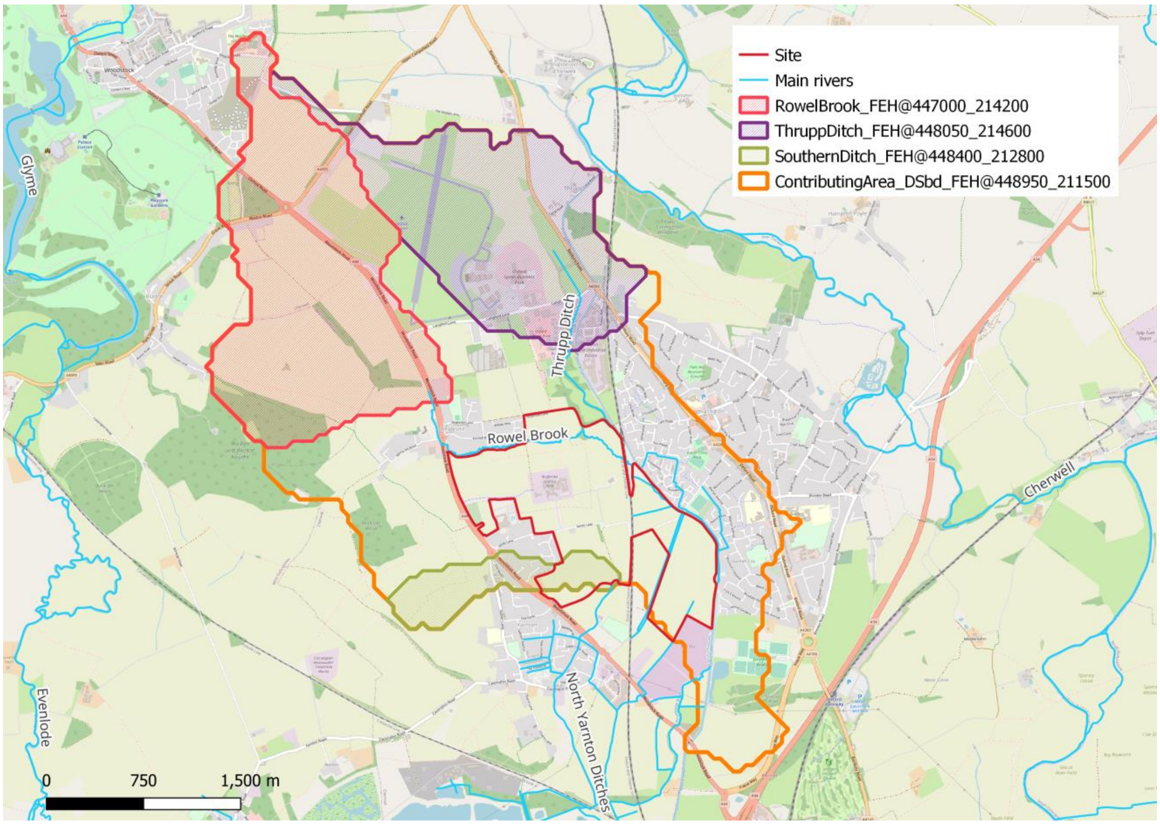

Figure 1 FEH catchments and site boundaries

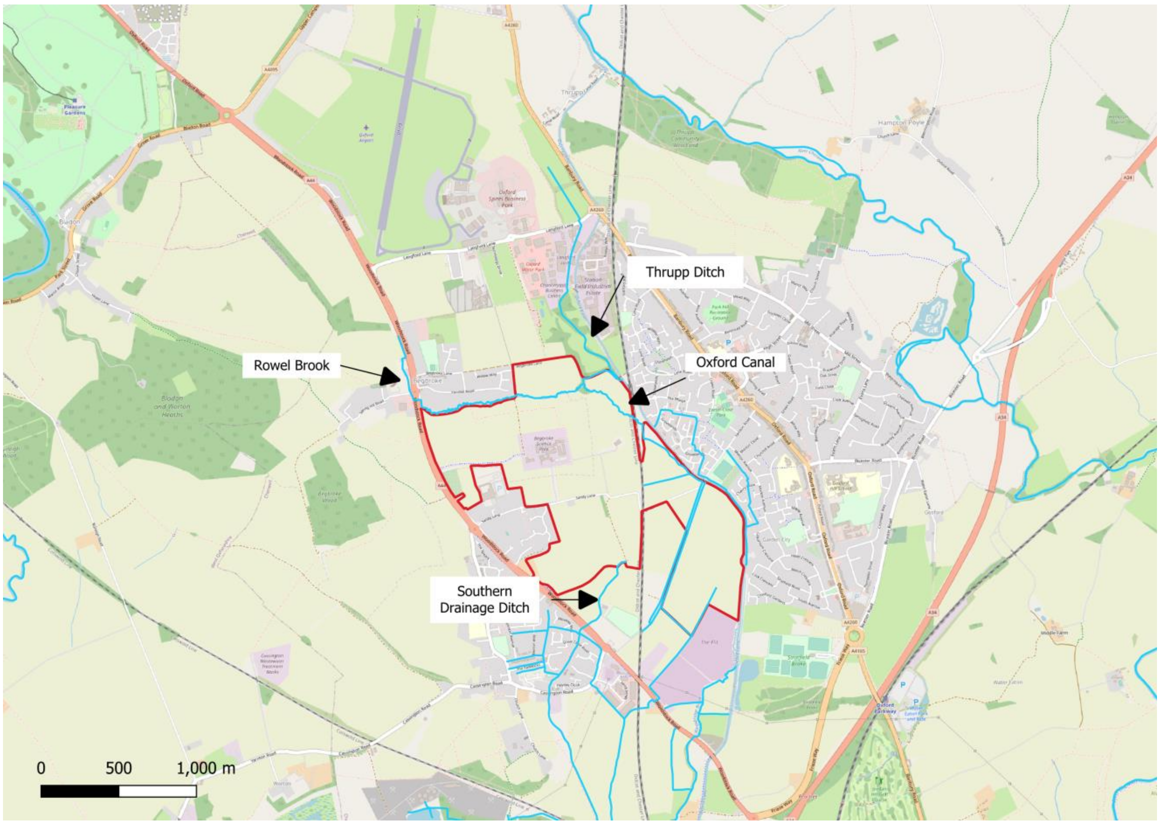

Figure 2 Watercourses in the area of interest

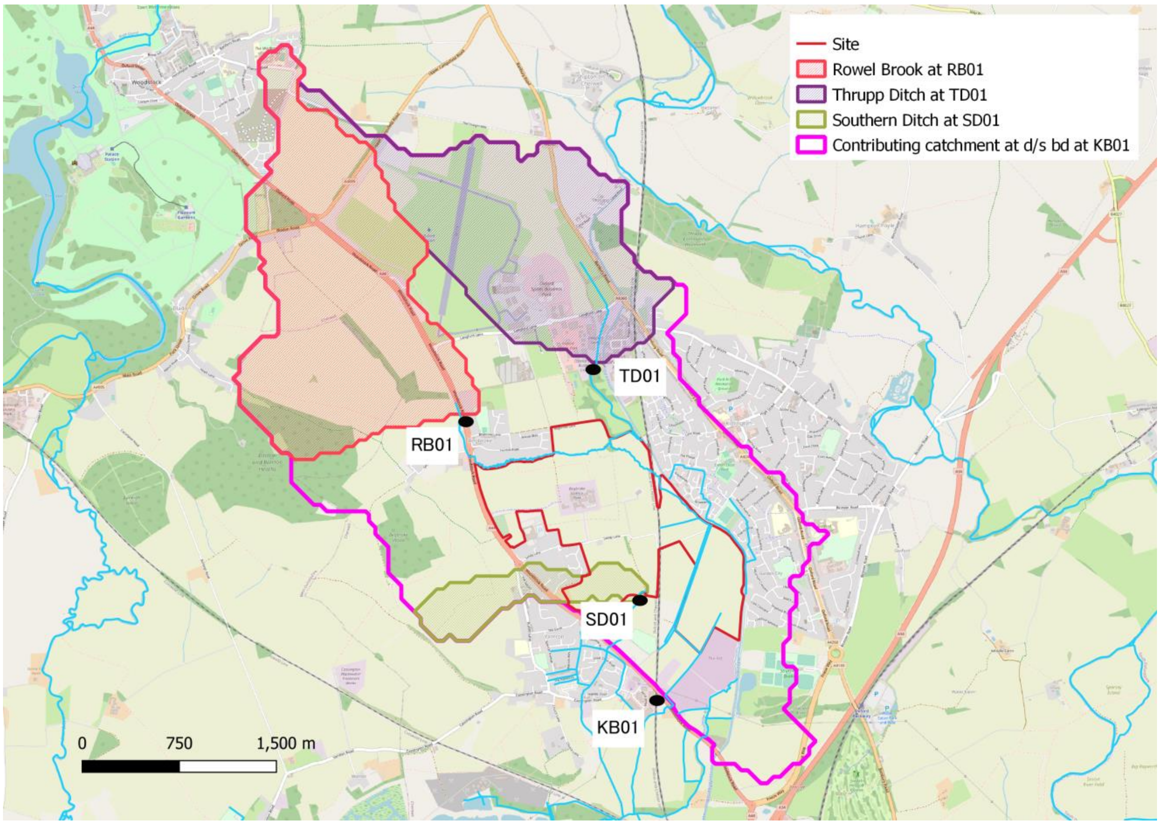

Figure 3 Locations selected for the purposes of the FEH analysis

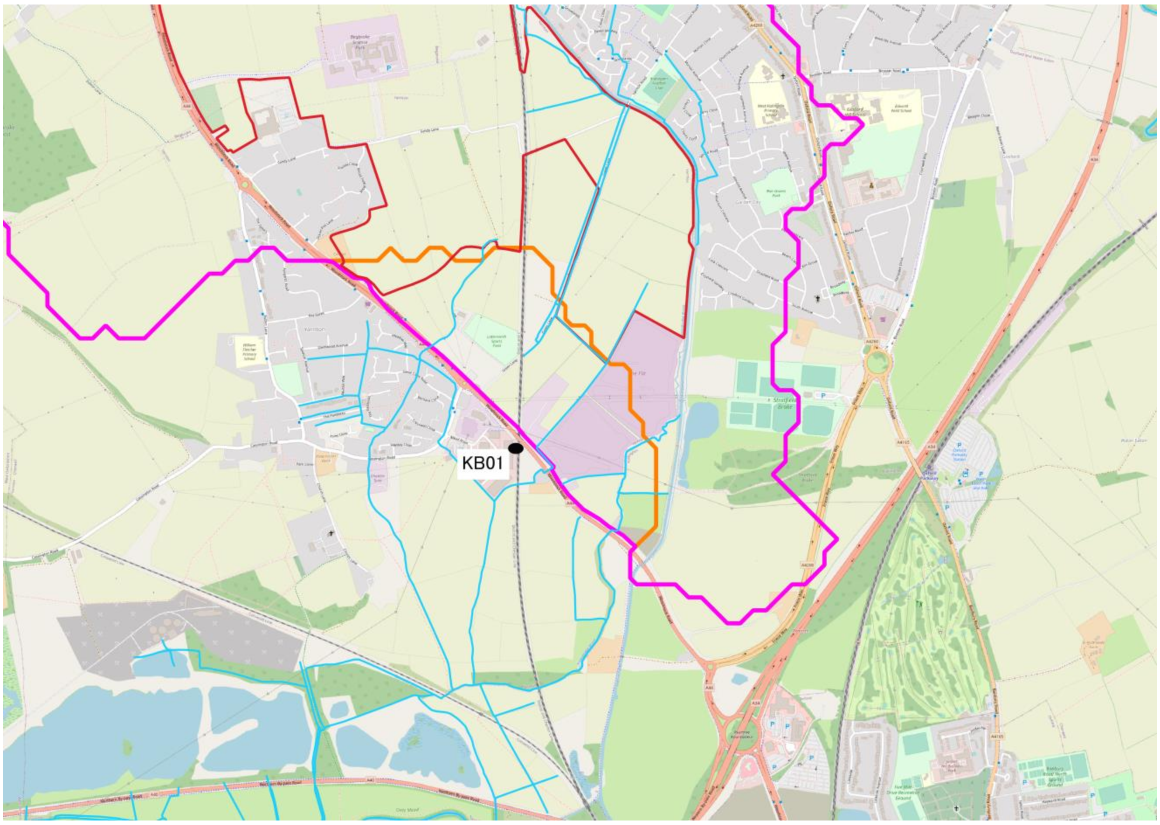

Figure 4 Changes to KB01 FEH catchment boundaries near the site

Catchment Description:

The main watercourses and ditches near and on the site of interest are shown in Figure 2. The Rowel Brook originates west of Oxford Airport and drains east the A44. It then turns south towards Begbroke, where is culverted and flows east across the northern boundary of the proposed development site. It then bifurcates, with the north eastern branch from the bifurcation flowing north and then east. This branch joins with the the Thrupp Ditch and discharges into the Oxford Canal. The south eastern branch of the Rowel Brook flows through the site, it passes through a culvert under the railway line and then flows along the eastern edge of the site. It then flows in a pair of ditches along either side of Yarnton Lane and is routed through field drainage and under the A44 south of the site.

The Thrupp ditch drains a catchment north of the site. It flows south, east of Oxford Airport and west of the Oxford Canal. It joins with the Rowel Brook and Oxford Canal on the north eastern boundary of the site.

The Southern drainage ditch originates to the west of the railway within the site boundary and flows southwest through Yarnton.

2.3 Hydrometric Data

Source of flood peak data:

NRFA v11, released September 2022, contains data up to the end of September 2021.

Gauging stations (flow and level):

Watercourse	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level…)	Start of record and end if station closed
River Thames	Days Weir		39002	3444.7	Miscellaneous	1938 - 2018

Data available at each flow gauging station:

Station name	Data source	Data type	Start and end of flood peak record	Update for this study?	OK for QMED?	OK for pooling?	Data quality check needed?	Station and flow data quality summary
Days Weir	1938 - 2018	AMAX	1938 - 2018	Outside scope	Yes	Yes	Outside scope	Calculated flows within 5% of measured flows, increasing to 10% at flows over 100m3/s.

Updates or revisions to flood peak data:

Outside scope

Data quality checks carried out:

Outside scope

Rating Equations:

Station name	Type of rating e.g., theoretical, empirical; degree of extrapolation	Rating review needed?	Comments and link to any rating reviews

Rating reviews:

Other data available and how it has been obtained:

Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings		No		
Historical flood data	Yes	Yes	EA Historic flood map and recorded flood outlines dataset.	Site is shown and there are some areas to the east of the site that have flooded in the past.
Flow or river level data for events		No		
Rainfall data for events		No		
Potential evaporation data		No		
Results from previous studies		No		
Other data or information		No		

Conclusions of hydrometric data review:

Station name	Rating suitability	Suitability for flood estimation calculations	Non-stationary analysis requirements
Thames@Days Weir	Rating formulae based upon gaugings - tailwater calibration applies for flows > 70 cumecs	Gauge is suitable as QMED donor for the purposes of this study	Not required

2.4 Hydrological understanding of the catchment

Plots of flood peak data and interpretation:

NA

Plots of flow data and interpretation:

NA

Plots of stage data and interpretation:

NA

Conceptual model:

The site of interest comprises the fields surrounding Oxford Science Park, as shown in Figure 1. Flooding is likely to be caused by the capacity of the Rowel Brook and nearby channels being exceeded, resulting in overland flow. Peak flows are of primary importance as finished floor levels for the proposed development will be informed by the hydraulic modelling driven by design flows estimated for this study. Only the potential sources of fluvial flooding are covered within this assessment.

The hydrological connectivity within the area of study is affected by the presence of numerous field drains and ditches and by the interaction of the main watercourses near the site of interest with the Oxford canal. Therefore, the implementation of standard FEH approaches has been aided by the implementation of a direct rainfall model to gain a more comprehensive understanding of hydrological connectivity and flow paths in the area of interest.

Unusual catchment features:

All FEH catchments in Figure 1 are classified as small. With respect to urbanisation levels, the following applies:

- Rowel Brook is classified as essentially rural;
- Thrupp ditch is classified as heavily urbanised;
- Southern drainage ditch and overall FEH catchment at d/s hydraulic model extent are both classified as moderately urbanised.

According to their BFIHOST19 values, all FEH catchments in Figure 1 except the Southern Drainage ditch catchment are classified as groundwater dominated, according to current FEH guidelines[2].

2.5 Initial choice of approach

Are FEH methods appropriate?

FEH methods are appropriate according to current FEH guidelines[2]. In line with the guidelines on the implementation of the Statistical method on small catchments, QMED should be adjusted by using one single donor and the small catchments method should be implemented in the pooling group selection process. The latest advice from the EA is, however, to assess the small catchments SDM approach against the standard SDM approach when deriving pooling groups using NRFAv11[3]. It should be noted, however, that a comparison of the recommended small catchments method with the standard method in pooling group selection has not been undertaken at this stage of analysis and will be carried out when the hydrological assessment is finalised in the next stage of analysis.

Current guidance on the implementation of ReFH2 on heavily urbanised catchments is to use:

- a Tp scaling factor of 1;
- a summer storm if the catchment is highly permeable (BFIHOST19 is > 0.65).

The indication is also for heavily urbanised catchments to treat the catchment as rural, as the small catchments research found that this approach would lead to more accurate flood frequency estimates, according to FEH guidelines[2]. The guidelines also suggest that the statistical method should be used in preference to the rainfall-runoff approach when estimating peak flows on groundwater dominated catchments.

Initial choice of method(s) and reasons:

The Statistical method and ReFH2 model are going to be applied to derive and compare peak flow estimates at the main inflow locations, namely RB01, TD01, and SD01 in Figure 3. The same standard FEH approaches are going to provide estimates for the FEH catchment at the d/s location KB01, also shown in Figure 3. It is anticipated that, given the characteristics of the study catchments, statistical estimates are going to be preferred. Hydrograph shapes are going to

2 LIT11832 Environment Agency Flood Estimation Guidelines, published 23/12/2022

3 Environment Agency, Flood estimation impacts of updating from NRFA v10 to v11 Evidence & Risk – National Flood Hydrology Team Published: 22/12/2022

be derived from ReFH2, with one or more appropriate storms selected to be applied across all subcatchments in order to represent the conditions maximizing flood risk at relevant locations.

How will hydrograph shapes be derived if needed?

ReFH2

Will the catchment be split into sub-catchments? If so, how?

The intervening area at KB01 is to be split into sub-catchments defined according to the DRM results.

Software to be used:

WINFAP5

ReFH2 version3.3

3. Locations where flood estimates are required

3.1 Summary of subject sites

Site code	Type of estimate: lumped (L) or sub-catchment (S)	Water-course	Site name / descrip-tion	Easting	Northing	AREA on FEH Web Service (km^2)	Revised AREA (if altered) (km^2)
RB01	L	Rowel Brook	Upstream inflow	446041	215112	3.24	n/a
TD01	L	Thrupp ditch	Upstream inflow	447477	215536	2.49	n/a
SD01	L	Southern drainage ditch	Upstream inflow	447443	212772	0.505	n/a
KB01	L	Kingsbridge Brook	Downstream estimation point	447376	214287	12.66	13.25
IC01	S	Kingsbridge Brook	Intervening catchment	447376	214287		7.015

3.2 Catchment Descriptors

Final catchment descriptors at each subject site:

Site code	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000	FPEXT
RB01	1	0.32	0.807	1.85	16.2	628	0.0167	0.1381
TD01	1	0.32	0.87	1.53	14.9	618	0.216	0.2098
SD01	1	0.32	0.637	1.02	24.4	619	0.088	0.1584
KB01	1	0.32	0.759	4.12	15.4	620	0.122	0.2049

Catchment boundary checks and revisions:

The only adjustment made to catchment boundaries is for the catchment at KB01 to include a small southern portion of the site not included in the original FEH catchment, thus increasing the catchment area to 13.25km^2 (see Figure 4). However, the assessment of the boundaries of the FEH catchment at KB01 against LiDAR DTM and knowledge of local features has highlighted that the catchment might not be well defined. It has, therefore, been assumed, that the overall FEH catchment at KB01 should be used as a base catchment for design peak flow and hydrograph calculations for the intervening area but a refinement to its boundaries would be needed. The results of the DRM model built for the area of interest are being used for this purpose. The DRM model has provided information about the flow paths which is also being used to refine catchment boundaries at the main inflow locations (RB01, TD01, and SD01) and the distribution of inflows from off and on site subcatchments to the main watercourses on site. Preliminary DRM results and subcatchments delineation are shown in Figure 5 and Figure 6.

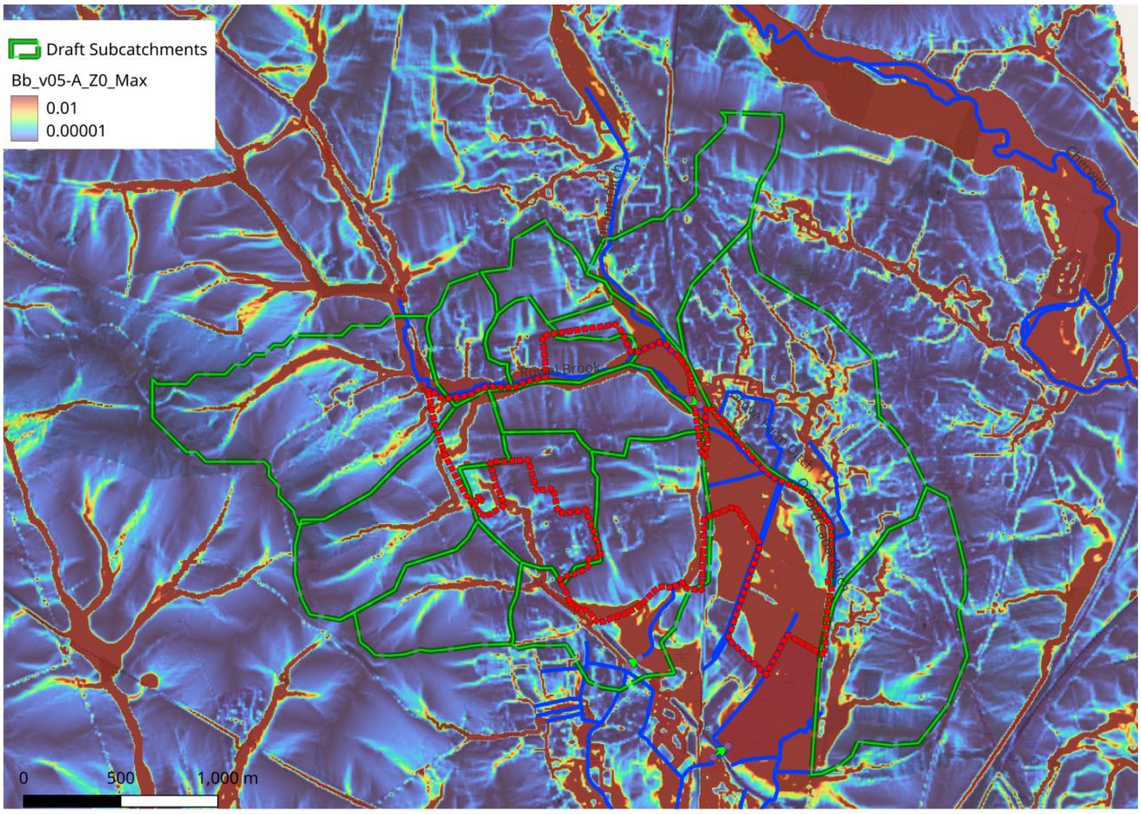

Figure 5 Preliminary results of the Direct Rainfall Model (unit flow, m2/s)

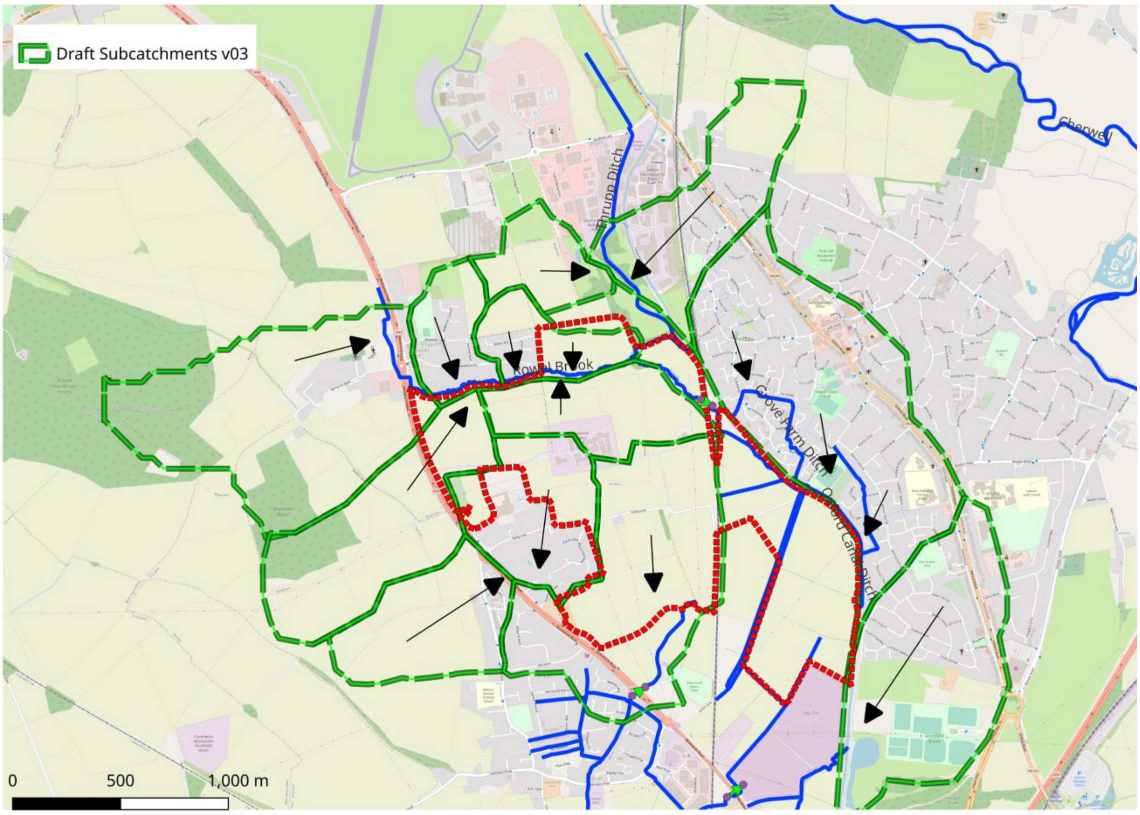

Figure 6 Draft subcatchments and associated direction of flow.

It should be noted, however, that the revision of FEH catchments boundaries and subcatchments delineation is likely to require further adjustments in the next stage of analysis upon gathering of additional information on local features and flow pathways. Therefore, at this stage of analysis, FEH catchments boundaries have not been amended and a preliminary FEH analysis has been carried out on the basis of FEH areas and associated descriptors as detailed in Tables 3.1 and 3.2. The outcome of this analysis is going to be revised once all adjustments have been finalised but it is anticipated that changes in terms of estimated peak flows are going to be relatively small.

URBEXT source and method for updating:

Default URBEXT2000 updated according to UEF (Section 2.3 FEH guidelines[2]) to present day.

BFIHOST source, checks and updates:

BFIHOST19 values are consistent with soils and geology maps. The area lies on a Limestone and mudstone sedimentary bedrock formation. The hydrological catchments include a variety of soils, mostly base-rich loamy and clayey.

Checks and revisions to other catchment descriptors:

FARL was checked against OS mapping and found to be appropriate.

4. Stationary statistical methods

4.1 Method overview

What is the purpose of applying these methods?

Peak flow estimation at all required inflow lacations and in addition at downstream location KB01.

What methods will be used to estimate QMED and growth curves?

Site code	Methods used for QMED	Methods used for growth curves
RB01	DT	
TD01	DT	
SD01	DT	
KB01	DT	Pooling, small catchment method

4.2 Estimating QMED

QMED at gauged subject sites:

Site code	Method (AM/ POT/LF)	Initial QMED (m^3/s)	Number of water years of data used	Adjustment for climatic variation?	Final QMED (m^3/s)

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

QMED at ungauged subject sites:

Site code	Method (CD/ DT/BCW)	Initial QMED (rural) from CDs (m^3/s)	Donors used (NRFA numbers)	Donor distances from subject centroid (km)	Individual donor weights	Combined and weighted donor adjustment factor	Urban adjustment factor	Final QMED (m^3/s)
RB01	DT	0.154	39002	15.28		1.020	1.045	0.164
TD01	DT	0.085	39002	16.76		1.015	1.901	0.164
SD01	DT	0.065	39002	16.52		1.022	1.142	0.075
KB01	DT	0.619	39002	16.51		1.019	1.289	0.814

Methods: CD - Catchment descriptors alone; DT - catchment descriptors with donor transfer; BCW - catchment descriptors with bankfull channel width.

Urban adjustment of QMED:

Urban adjustment procedures applied in WINFAP5 based on updated URBEXT2000 to present day.

Search for donor sites:

The search for potential suitable donors to all subject sites has mainly focused on evaluating the suitability of the closest gauge. This is also in line with current guidance on peak flow estimation on small catchments. The closest NRFA gauge to all subject sites except TD01 is 39002 (Thames@DaysWeir). The guage is approximately 15-16km away from all subject sites. Despite being characterised by a catchment area substiantially larger than all subject sites, 39002 has been selected as QMED donor, as it is a suitable donor and also provides conservative estimates of QMED at allnsubject sites. With respect to TD01, gauge 39002 is the second nearest suitable gauge to the subject site, the closest gauge being NRFA 39034 (Evenlode@Cassington). However, 39002 provides a more conservative estimate and has also been selected to ensure consistency in the donor adjustment factors calculated across the area of study.

Donor sites chosen and QMED adjustment factors:

NRFA no.	Method (AM/ POT/LF)	Adjustment for climatic variation?	QMED from flow data (m^3/s)	De-urbanised QMED from flow data (m^3/s) (A)	QMED from catchment descriptors (m^3/s) (B)	Adjustment ratio (A/B)
39002	AM	No	148.014	141.243	133.189	1.060

Methods: AM – Annual maxima; POT – Peaks over threshold; LF – Low flow (flow duration curve) statistics.

4.3 Estimating growth curves

Derivation of growth curves at subject sites:

Site code	Method (SS, P, ESS, H.)	If P or ESS, name of pooling group	Distribution used and reason for choice	Any urban or non-flood years adjustments	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
KB01	P	KB01	GL, best fit	Urban	1 0.291 -0.218	3.298

Methods: SS - Single Site; P - Pooled; ESS - Enhanced Single Site; H - Historical. Pooled and ESS growth curves were derived using the procedures from Science Report SC050050 (2008). Urban adjustments are carried out using the method of Kjeldsen (2010).

Flood frequency curve plots:

Derivation of pooling groups:

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (ESS)	URBEXT2000 threshold applied to pooling group selection?	L-moments deurbanised (including subject site for ESS)?	Small catchment pooling procedure applied?
KB01	KB01	No	0.03	Yes	Yes

Methods: Unless otherwise stated, pooling groups were derived using the procedures from Science Report SC050050 (2008). The small catchment pooling procedure is given in the report on Phase 2 of project SC090031 (2021) and implemented in WINFAP v5.

Pooling group composition:

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
PG01	According to EA recommendation[3], gauge 26017 Ings Beck@South Newbald was removed from the default pooling group. This was found to be heterogeneous. A review of the pooling group was undertaken based on the distribution of L-moments. Therefore, the NRFA gauges 27073, 25019, 27051, 39033, 33054, 7011 were all further investigated. The review of information available on the NRFA did not provide justification for the removal of theses gauges from the default pooling group. No other gauge has been	0.305 0.197

Name of group	Changes made to default pooling group, with reasons	Weighted average L-moments
	added to the pooling group.	

4.4 Final choice of QMED and growth curves

Method choice and reasons:

Site code	Final choice of QMED and reasons	Final choice of flood growth curve method and reasons
RB01	Urban/donor adjusted QMED; best estimate based on available data	
TD01	Urban/donor adjusted QMED; best estimate based on available data	
SD01	Urban/donor adjusted QMED; best estimate based on available data	
KB01	Urban/donor adjusted QMED; best estimate based on available data	Pooled growth curve based on GL distribution, small catchments pooling method. Best fit.

Final flood estimates from stationary statistical methods:

Site code	2 50%	5 20%	10 10%	30 3.3%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
RB01	0.164	0.241	0.298	0.401	0.456	0.541	0.639	0.792	0.931
TD01	0.164	0.241	0.298	0.401	0.456	0.541	0.639	0.792	0.931
SD01	0.075	0.110	0.137	0.183	0.209	0.247	0.292	0.362	0.426
KB01	0.814	1.197	1.481	1.99	2.263	2.683	3.169	3.932	4.618

Flood peak in m^3/s for the return periods in years or AEP (%) events.

5. Non-stationary statistical methods

5.1 Method Overview

What is the purpose of applying these methods?

What methods will be used?

Site code	If ungauged, which gauging station is being used?	Methods used to test for trends and change points	Methods used for non-stationary frequency analysis

5.2 Testing for trends and change points

Non-parametric trend tests:

Step change tests:

Split sample tests:

Interpretation and conclusions:

5.3 Non-stationary frequency analysis

Selection of covariates:

Fitting non-stationary models:

Interpretation and conclusions:

Final flood estimates from non-stationary statistical methods:

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.3%	100 1%	200 0.5%	1000 0.1%

Flood peak in m^3/s for the return periods in years or AEP (%) events.

6. Revitalised flood hydrograph (ReFH1) method

6.1 Method Overview

What is the purpose of applying this method?

Rural and urban catchment sub-divisions:

6.2 Model Parameters

Summary of model parameters:

Site code	Method	Tp (hours) rural	Tp (hours) urban	Cmax (mm)	BL (hours)	BR	PR_{imp} %

Methods: OPT: Optimisation from event analysis, BR: Baseflow recession fitting, LAG: TP from lag analysis, CD: Catchment descriptors, DT: Data transfer, CAL: model calibration.

Analysis undertaken to derive model parameters:

6.3 Model inputs for design events

Design events for lumped catchments:

Site code	Rainfall DDF model	Urban or rural	Season of design event	Storm duration (hrs)	Initial soil moisture Cini	Initial baseflow BFO

Design events for subcatchments and intervening areas:

Site code(s)	Rainfall DDF model	Season of design event	Storm duration (hrs)	Storm area for ARF	Areal reduction factor (ARF)	Reason for selecting storm

Storm duration testing:

6.4 Final choice of ReFH1 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters

Final flood estimates from ReFH1 method:

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.3%	100 1%	200 0.5%	1000 0.1%

Flood peak in m^3/s for the return periods in years or AEP (%) events.

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7. Revitalised flood hydrograph 2 (ReFH2) method

7.1 Method Overview

What is the purpose of applying this method?

Rural and urban catchment sub-divisions:

Version of ReFH2 applied:

7.2 Model Parameters

Summary of model parameters:

Site code	Method	Tp (hours) rural	Cmax (mm)	BL (hours)	Area modelled as urban (km2)	TP urban scaling factor	IF	IRF	DS
RB01	CD	4.123	918.421	52.417	0.0848	0.75	0.4	0.7	0.5
TD01	CD	3.798	1081.717	52.635	0.8428	1	0.4	0.7	0.5
SD01	CD	2.575	590.556	39.883	0.0696	0.75	0.4	0.7	0.5
KB01	CD	6.624	810.759	60.14	2.533	0.75	0.4	0.7	0.5

Methods: OPT: Optimisation from event analysis, BR: Baseflow recession fitting, LAG: TP from lag analysis, CD: Catchment descriptors, DT: Data transfer, CAL: model calibration.

Analysis undertaken to derive model parameters:

7.3 Model inputs for design events

Design events for lumped catchments:

Site code	Rainfall DDF model	Urban or rural	Highly permeable?	Season of design event	Storm duration (hrs)	Initial soil moisture Cini	Initial baseflow BFO
RB01	DDF13	Rural	Yes	Winter	6.5	60.746	0
TD01	DDF13	Rural	Yes	Summer	6.5	27.742	0
SD01	DDF13	Rural	No	Winter	4.5	79.134	0.004
KB01	DDF13	Rural	Yes	Winter	11	65.455	0

Design events for subcatchments and intervening areas:

Site code(s)	Rainfall DDF model	Season of design event	Storm duration (hrs)	Storm area for ARF	Areal reduction factor ARF	Reason for selecting storm
To be finalised in the next stage of analysis						

Storm duration testing:

To be carried out in the next stage of analysis and is going to be based on a selection of design storms to be applied to all lumped inflows and subcatchments in order to represent to occurrence of conditions maximizing flood risk to the site.

7.4 Final choice of ReFH2 flow estimates

Method choice and reasons:

Site code	Final choice of design inputs and model parameters
To be finalised in the next stage of analysis	

Final flood estimates from ReFH2 method:

Site code	2 50%	5 20%	10 10%	30 3.3%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
RB01	0.17	0.25	0.31	0.41	0.47	0.56	0.67	0.85	1

Site code	2 50%	5 20%	10 10%	30 3.3%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
TD01	0.31	0.45	0.55	0.73	0.83	0.98	1.16	1.45	1.7
SD01	0.07	0.1	0.12	0.16	0.18	0.22	0.26	0.32	0.38
KB01	0.62	0.89	1.09	1.45	1.66	1.99	2.38	3	3.53

Flood peak in m^3/s for the return periods in years or AEP (%) events.

8. Other Rainfall-Runoff or Hydrograph Methods

8.1 Averaged Hydrograph Shapes

8.2 FSR-FEH Rainfall-Runoff Method

8.3 Direct Rainfall Modelling

9. Discussion and summary of results

9.1 Comparison of results from different methods

Site code	*Ratio of ReFH2 to stationary statistical peak, 50% AEP*	*Ratio of ReFH2 to stationary statistical peak, 1% AEP*
RB01	1.037	1.035
TD01	1.89	1.812
SD01	0.933	0.889
KB01	0.762	0.742

9.2 Final choice of method

Choice of method and reasons:

The statistical estimates (with QMED from catchment descriptors and adjusted by donor transfer and for urbanisation) have been selected as final. A comparison between statistical and ReFH2 estimates has highlighted that there is a discrepancy between the two methods, with over or under estimation from either of them which is not consistent across all subject catchments. However, for all sites but SD01 current FEH guidelines would recommend the statistical method in preference to ReFH2, given the characteristics of the subject sites. Therefore, the statistical method has been selected to derive the final peak estimates at all sites. Hydrograph shapes are from ReFH2 and design hydrographs are derived from ReFH2 hydrographs scaled to match the statistical peaks. Design flows for the intervening area IC01 have been obtained from design flows estimated at KB01 scaled down by the ratio of catchment areas.

How will the 0.1% AEP flows be estimated?

Peak flows from Statistical method

How will the flows be applied to a hydraulic model?

Lumped inflows at RB01, TD01, and SD01. Design flows for the intervening area IC01 (see 9.3) are going to be applied as lumped or distributed inflows across all subcatchments defined on the basis of the results of the direct rainfall modelling.

9.3 Final results

Site code	2 50%	5 20%	10 10%	30 3.3%	50 2%	100 1%	200 0.5%	500 0.2%	1000 0.1%
RB01	0.164	0.241	0.298	0.401	0.456	0.541	0.639	0.792	0.931
TD01	0.164	0.241	0.298	0.401	0.456	0.541	0.639	0.792	0.931
SD01	0.075	0.110	0.137	0.183	0.209	0.247	0.292	0.362	0.426
KB01	0.814	1.197	1.481	1.99	2.263	2.683	3.169	3.932	4.618
IC01	0.431	0.634	0.784	1.054	120%	1.420	1.678	2.082	2.445

Flood peak in m^3/s for the return periods in years or AEP (%) events.

Design storms applied in the hydraulic model:

Site code(s)	Season of design event	Storm duration (hrs)	Storm area for ARF (km2)	Return period(s)	Reason for selecting storm
To be selected in the next stage of analysis					

Climate change allowances:

9.4 Checks

Growth factor checks:

Site code	1% AEP growth factor	0.1% AEP / 1% AEP ratio
KB01	3.296	1.721

Specific discharge:

Site code	2 50%	5 20%	10 10%	20 5%	30 3.3%	50 2%	75 1.3%	100 1%	200 0.5%	1000 0.1%

Flood peak in l/s/ha for the return periods in years or AEP (%) events.

Spatial consistency of results:

To be assessed when hydrological assessment is finalised

Return periods for notable historic floods:

NA

Compatibility with longer-term flood history:

NA

Comparisons with previous studies:

NA

Checks on hydraulic model results:

Not carried out at this stage of analysis

9.5 Assumptions, limitations, and uncertainty

Assumptions (specific to this study):

- QMED and pooling suitability assessed on the basis of information available on the NRFA; no local gauge available
- Adjustment to catchment boundaries and distribution of contributing runoff to local watercourses is made in accordance to the topography of the area and the results of a direct rainfall model. Thus, it is assumed that surface runoff processes are most likely to inform a correct representation of the subcatchments contributions across the study area.

Limitations:

- Statistical method applied outside AEPs range of applicability;
- Hydrological catchments of interest are all ungauged. Hydrological response is highly affected by local topographical features and alterations to hydrological connectivity due to artificial drainage. While a better understanding of flow paths within the area of interest has been achieved through direct rainfall modelling, the lack of local hydrometric data remains a key limitation in the results.

Uncertainty:

Site code	50% AEP Lower 95%	50% AEP Upper 95%	5% AEP Lower 95%	5% AEP Upper 95%	1% AEP Lower 95%	1% AEP Upper 95%	0.1% AEP Lower 95%	0.1% AEP Upper 95%
To be assessed when hydrological assessment is finalised								

Upper and lower 95% confidence bounds for the flood peak in m^3/s for the AEP (%) events.

Suitability of results for future studies:

Assessment of flood risk specific to the area of interest of current project.

Recommendations for future work:

To be made when hydrological assessment is finalised

10. Appendix

10.1 Digital files

Input data:

Project or calculation files:

Output data:

10.2 Other Supporting Information

Table 1 Pooling group at KB01

	Station	Distance (SDM)	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
1	27073 (Brompton Beck @ Snainton Ings	0.585	41	0.820	0.212	**0.213**	0.006	**0.005**	0.838
2	26016 (Gypsey Race @ Kirby Grindalyth	0.589	24	0.103	0.304	**0.304**	0.240	**0.240**	0.088
3	36010 (Bumpstead Brook @ Broad Gree	0.600	54	7.545	0.372	**0.374**	0.168	**0.167**	1.183
4	26014 (Water Forlornes @ Driffield)	0.829	23	0.437	0.315	**0.316**	0.164	**0.163**	0.350
5	25019 (Leven @ Easby)	0.842	43	5.677	0.334	**0.335**	0.373	**0.372**	0.747
6	27051 (Crimple @ Burn Bridge)	0.997	49	4.564	0.217	**0.218**	0.143	**0.142**	0.785
7	39033 (Winterbourne Stream @ Bagnor)	1.058	59	0.403	0.338	**0.338**	0.375	**0.375**	1.178
8	36004 (Chad Brook @ Long Melford)	1.066	54	4.873	0.301	**0.302**	0.170	**0.169**	0.458
9	33054 (Babingley @ Castle Rising)	1.067	45	1.136	0.229	**0.229**	0.183	**0.182**	1.109
10	7011 (Black Burn @ Pluscarden Abbey)	1.102	9	5.205	0.491	**0.491**	0.521	**0.521**	2.431
11	26013 (Driffield Trout Stream @ Driffield)	1.144	11	2.700	0.281	**0.282**	0.196	**0.195**	2.597
12	36003 (Box @ Polstead)	1.180	61	3.900	0.311	**0.313**	0.082	**0.080**	1.001
13	33032 (Heacham @ Heacham)	1.181	53	0.449	0.297	**0.298**	0.129	**0.128**	0.234
14									
15	Rejected Stations								
16	26017 (Ings Beck @ South Newbald)	0.368	22	0.502	0.215	0.216	0.060	0.059	
17									
18									

Appendix E Surface Water Drainage Strategy

BURO HAPPOLD

Begbroke Innovation District

Outline Drainage Strategy

BEG-BUR-XX-XX-RP-XX-00001-Drainage

0052188

19 July 2023

Revision P01

Revision	Description	Issued by	Date	Checked
P01	Draft Issue	TW	19/07/23	JW

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author	**Thomas Whiter**
date	**19/07/2023**
approved	**John Waiting**
signature	
date	

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Glossary

Term	Definition
BID	Begbroke Innovation District
CC	Climate Change
EA	Environmental Agency
LLFA	Lead Local Flood Authority
OCC	Oxfordshire County Council
OUD	Oxford University Development
SuDS	Sustainable Drainage Systems
TW	Thames Water

1 Introduction

1.1 Background

This outline drainage strategy has been prepared by Buro Happold on behalf of the Oxford University Developments Ltd. (OUD), in support of an outline planning application for the Begbroke Innovation District (BID).

In preparing the strategy, the existing foul and surface water drainage infrastructure has been assessed regarding the demands of the development proposals. In addition, the impact of the proposed surface water infrastructure on existing water courses has been reviewed in conjunction with a flood risk assessment to ensure no increased flows or flood risk will occur.

The strategy has also drawn on information contained in the following documents

- Masterplan and Area Schedule, (HB, Jan 2023).
- Utilities Asset Report (Groundwise, July 2022).
- Green Infrastructure Parameter Plan (HB, May 2023).
- Flood Risk Assessment (Buro Happold, May 2023).
- Local Standards and Guidance for Surface Water Drainage on Major Development in Oxfordshire (Oxfordshire County Council, December 2021)
- Hydrock Desk Study review and GIR 19114-HYD-XX-XX-RP-GE-1002-S2-P7.

The report sets out the anticipated measures that could be incorporated into the detailed design and later planning stages in order to control both the quantity and quality surface water and quantity of foul water discharged from the Site.

Detailed foul and surface water designs are anticipated to be submitted to the local planning authority prior to the commencement of the relevant part of the Proposed Development, following consultation with relevant stakeholders as necessary. This will ensure that the foul and surface water drainage details are appropriately designed and controlled.

1.2 Site Description

The Site is located within the administrative boundary of Oxfordshire County Council (acting as the Lead Local Flood Authority) and within Cherwell District Council (acting as the Local Planning Authority). The Site location is shown in Figure 1-1 and the Site extents shown in Figure 1-2. It is located approximately 5 miles northwest of Oxford, in between the villages of Begbroke, Kidlington and Yarnton. The total Site area is approximately 170ha.

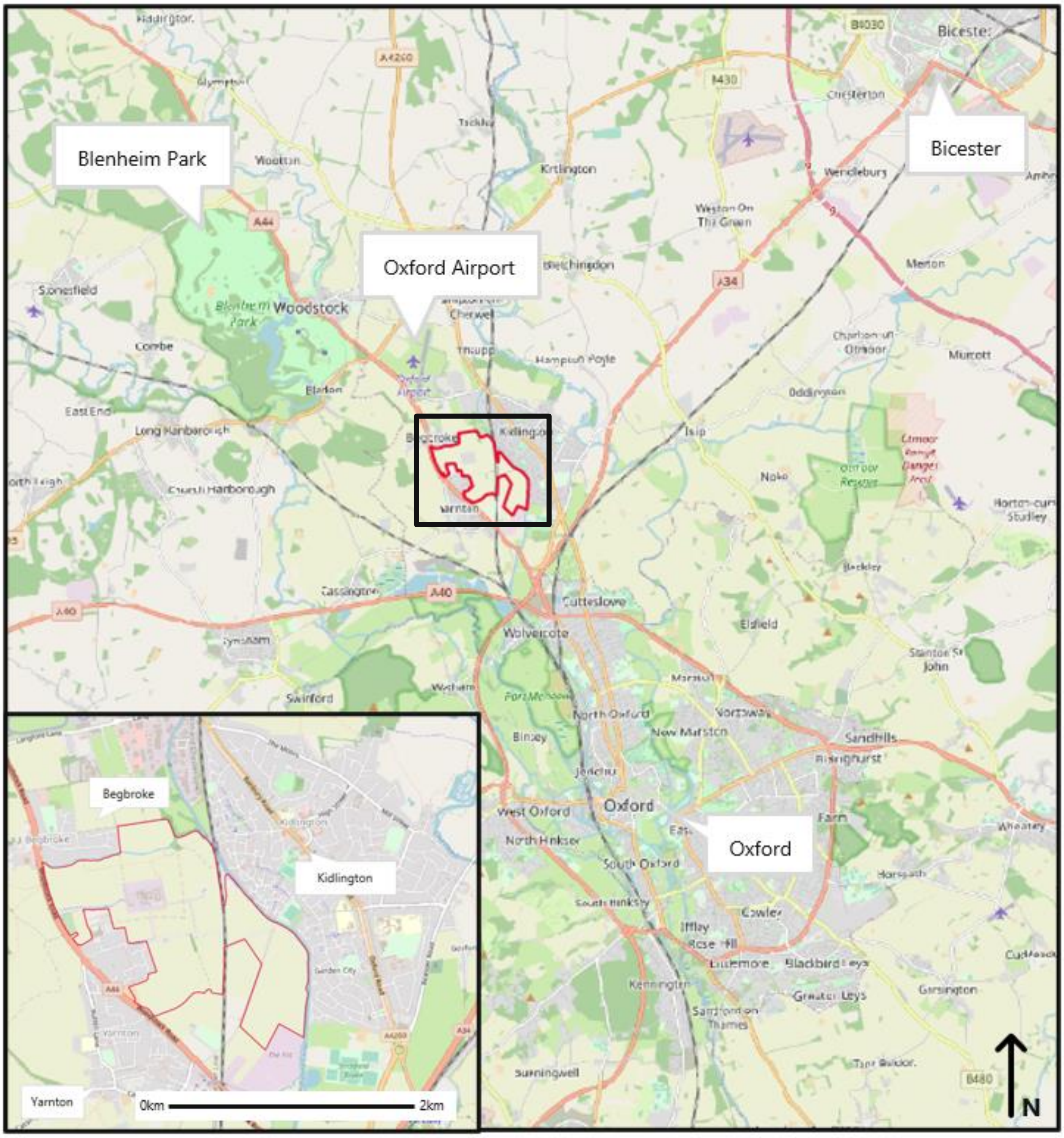


Figure 1—1 – Site Location and Red Line Boundary

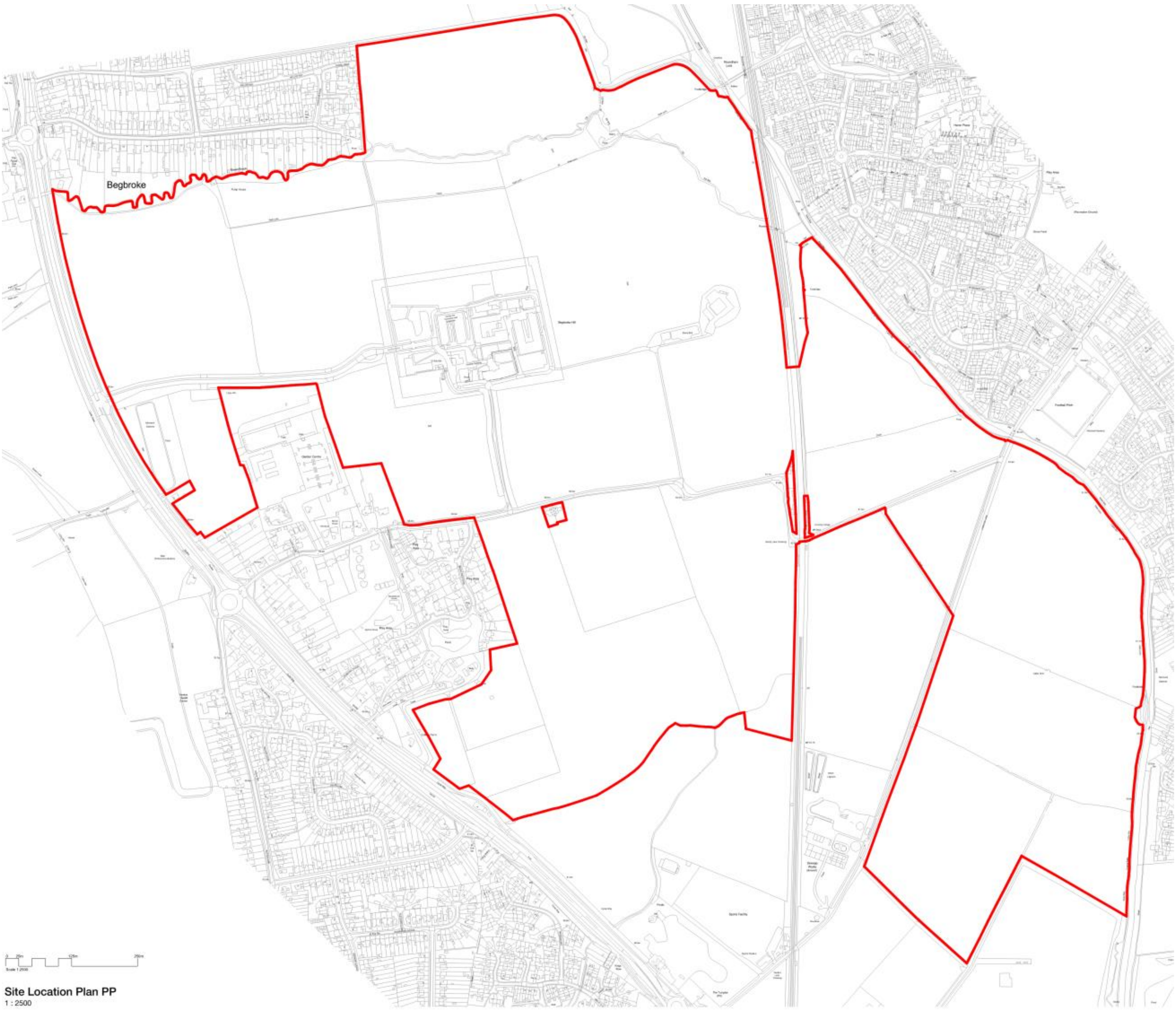


Figure 1—2 – Site Red Line Boundary (Hawkins Brown, BEG-HBA-SW-00-SK-A-SK80)

The Site is bound by the A44 Woodstock Road to the west, Rowel Brook to the north and Oxford Canal to the east. The Cherwell Valley railway line intersects the Site from north to south, in the east of the Site. Oxford Airport is located to the north of the Site.

The Site mainly comprises open greenfield land used for arable farming, with Begbroke Science Park (BSP) located at the centre. A number of individual dwellings are situated within the Site boundary, and the Yarnton Home and Garden Centre sits within the west of the Site. Rushy Meadows site of Special Scientific Interest (SSSI) is situated adjacent to the north-eastern boundary of the Site, adjacent to the Oxford Canal.

Access to BSP is provided via Begbroke Hill connecting with the A44 in the west. A number of key roads intersect the Site, providing east/west access, including Begbroke Hill and Sandy Lane. Sandy Lane crosses both the Cherwell Valley railway line (via level crossing) and Oxford Canal (via bridge) on its route towards Yarnton Lane and into Kidlington.

1.3 Proposed Development

The Proposed Development is a phased, mixed-use development which would encompass the expansion of the existing Begbroke Science Park, residential and associated amenity, education, and community uses. The Description of Development is as follows:

- Up to 215,000 square metres gross external area of residential floorspace within Use Class C3/C4 and large houses of multiple occupation (Sui Generis);
- Supporting social infrastructure including secondary school/primary school(s) (Use Class F1); health, indoor sport and recreation, emergency, and nursery facilities (Class E(d)-(f))
- Supporting retail, leisure and community uses, including retail (Class E(a)), cafes and restaurants (Class E(b)), commercial and professional services (Class E(c)), local community uses (Class F2), and other local centre uses within a Sui Generis use including public houses, bars and drinking establishments (including with expanded food provision), hot food takeaways, venues for live music performance, theatre, and cinema.
- Up to 155,000 square metres gross external area of flexible employment uses including research and development, office and workspace and associated uses (Use E(g)), industrial (Use Class B2) and storage (Use Class B8) in connection with the expansion of Begbroke Science Park;
- Highway works, including new vehicular, cyclist and pedestrian roads and paths, improvements to the existing Sandy Lane and Begbroke Hill road, a bridge over the Oxford Canal, safeguarded land for a rail halt, and car and cycle parking with associated electric vehicle charging infrastructure;
- Landscape and public realm, including areas for sustainable urban drainage systems, allotments, biodiversity areas, outdoor play and sports facilities (Use Class F2(c));
- Utility, energy, water, and waste water facilities and infrastructure;
- together with enabling and associated works, including temporary meanwhile uses.

Figure 1—3 – Illustrative Masterplan Layout

2 Legislation, Planning and Guidance

2.1 Legislation Context

The following is a list of the relevant legislation regarding water resources in the United Kingdom:

The Water Resource Act (1991) as amended (2009);

The Water Act (2014);

The Environment Act (1995);

The Environmental Protection Act (1990);

The Flood and Water Management Act (2010);

The Groundwater (England and Wales) Regulations 2009;

The Anti-Pollution Works Regulations (1999);

The Water Supply (Water Quality) Regulations (2018);

The Control of Pollution (Oil Storage) (England) Regulations (2001);

The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017; and

The Environment Damage (Prevention and Remediation) (England) Regulations 2015 (as amended).

2.2 Water Resources Act 1991 (WRA 1991)

The Water Resources Act (WRA) 1991 consolidates previous water legislation in respect of both the quality and quantity of water resources. Under Section 85 of the WRA 1991 it is an offence to cause or knowingly permit polluting matter to enter into "controlled waters", that is rivers, estuaries, coastal waters or groundwater, without permission. Permission is generally obtained as a discharge consent granted by the EA. The EA sets conditions which may control volumes and concentrations of particular substances or impose broader controls on the nature of the effluent. Each consent is based on the river quality objective (RQO) set by the EA for the quality of the stretch of water to which the discharge is made, as well as any relevant standards from EC Directives. The EA may also refuse an application for a discharge consent.

2.3 Policy Context

The management of water resources is governed by a range of legislative guidance set out within international, national and regional policy. This Strategy has been prepared with due regard to all relevant legislation, policy and guidance relating to both foul and surface water drainage.

2.3.1 Planning Policy and Guidance

This Drainage Strategy has been developed in accordance with the following policies and guidelines:

National Planning Policy Framework July 2021

Local Standards and Guidance for Surface Water Drainage on Major Development in Oxfordshire

CIRIA The SuDS Manual C753, 2015

Design and Construction Guidance for foul and surface water sewers offered for adoption under the Code for adoption agreements for water and sewerage companies operating wholly or mainly in England ("the Code")

Thames Water Local practices to support Code for Adoption Sewerage – Pumping Stations

Oxfordshire County Council Local Standards and Guidance for Surface Water Drainage on Major Development in Oxfordshire (December, 2021);

Oxfordshire County Council Key Design Criteria for Secondary School Sites (undated);

The Cherwell Local Plan 2011 – 2031 (July 2015); and

The Cherwell Local Plan Part 1 Partial Review (September 2020).

2.4 National Policies

2.4.1 National Planning Policy Framework (NPPF)

The NPPF sets out the Government's planning policies for England and provides guidance on its application. Amongst other things, the NPPF seeks to meet the challenge of climate change, flooding and coastal change, including by requiring development proposals to incorporate sustainable urban drainage systems (SuDS) unless inappropriate.

2.4.2 Flooding and Water Management Act 2010

The Flooding and Water Management Act (2010) requires developers to consider SuDS. In all instances developers should aim to reduce the rate of water runoff from sites.

2.4.3 Local Standards and Guidance for Surface Water Drainage on Major Development in Oxfordshire

The Local Standards and Guidance for Surface Water Drainage on Major Development in Oxfordshire assists developers in the guidance of surface water drainage systems and supports Local Planning Authorities in considering drainage proposals for new developments within Oxfordshire.

3 Existing Drainage

3.1 Existing Surface Water Drainage Features

There are two watercourses on the northern and southern extents of the Site respectively. Each has been designated by the EA as a main river.

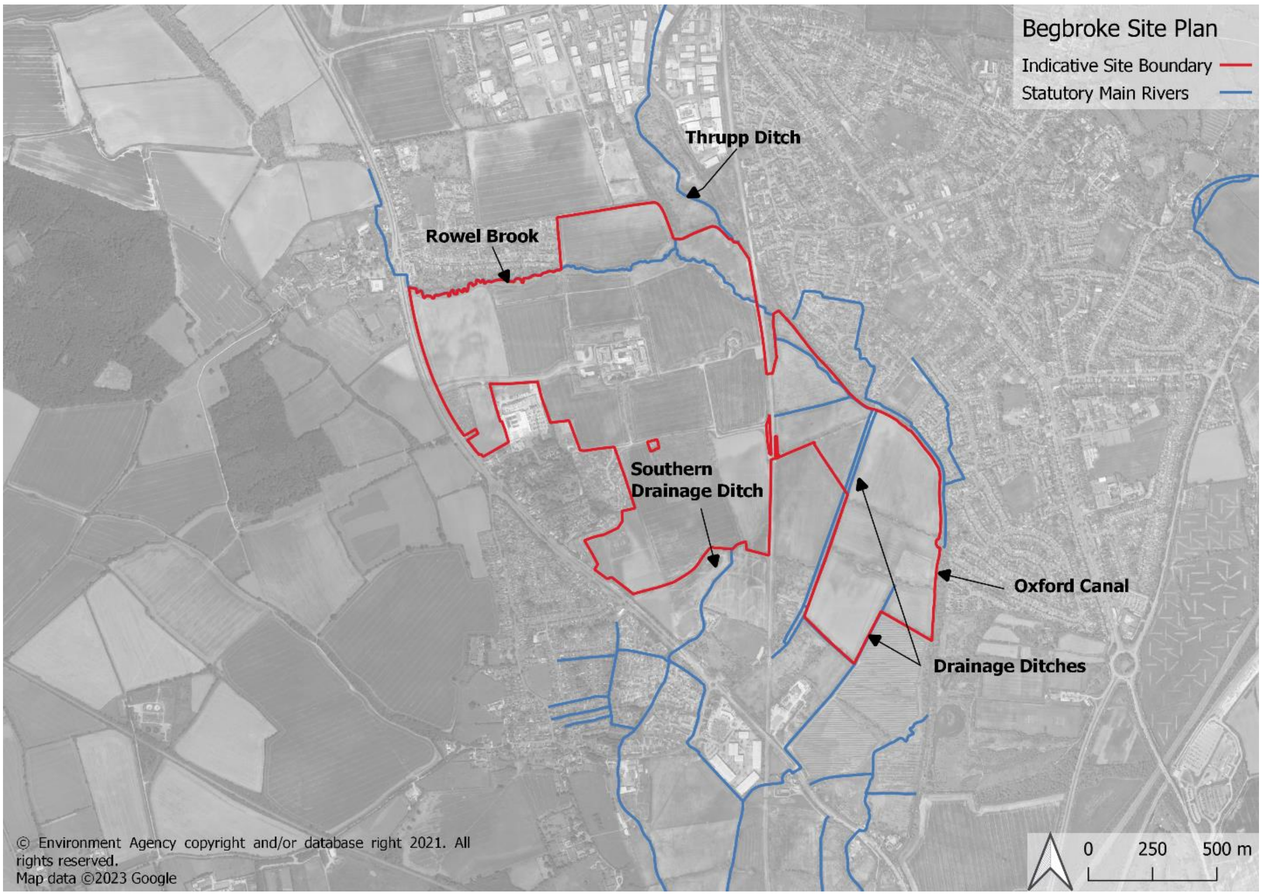


Figure 3—1 Existing Surface Water feature locations

Rowel Brook bounds the northern edge of the Site running west to east before splitting to the north and the south. The northern section continues east to the Oxford Canal. The southern section continues east under the existing railway, through a culvert, then onto the eastern paddocks.

The Southern Drainage Ditch collects overland flow to the south of Sandy Lane before conveying in under the A44 via a culvert then further southwest.

The Oxford Canal is outside of the Site boundary but closely follows the eastern boundary of the Site.

3.2 Existing Foul Drainage Infrastructure

Details of the existing sewer sizes and location of the surrounding network have been taken from Thames Water's (TW) asset plan and compiled by Groundwise in Appendix A. Figure 3—2 – **Existing Foul Water Layout** shows the location of existing TW sewers within the Site, these include five active rising mains and two abandoned sewers. All the sewers crossing the Site will require diversion. An application for the public sewer rising main and sludge main diversions has been made with a Section 185 application in line with Figure 3-3 below and detailed in Appendix F.

Figure 3—2 – Existing Foul Water Layout

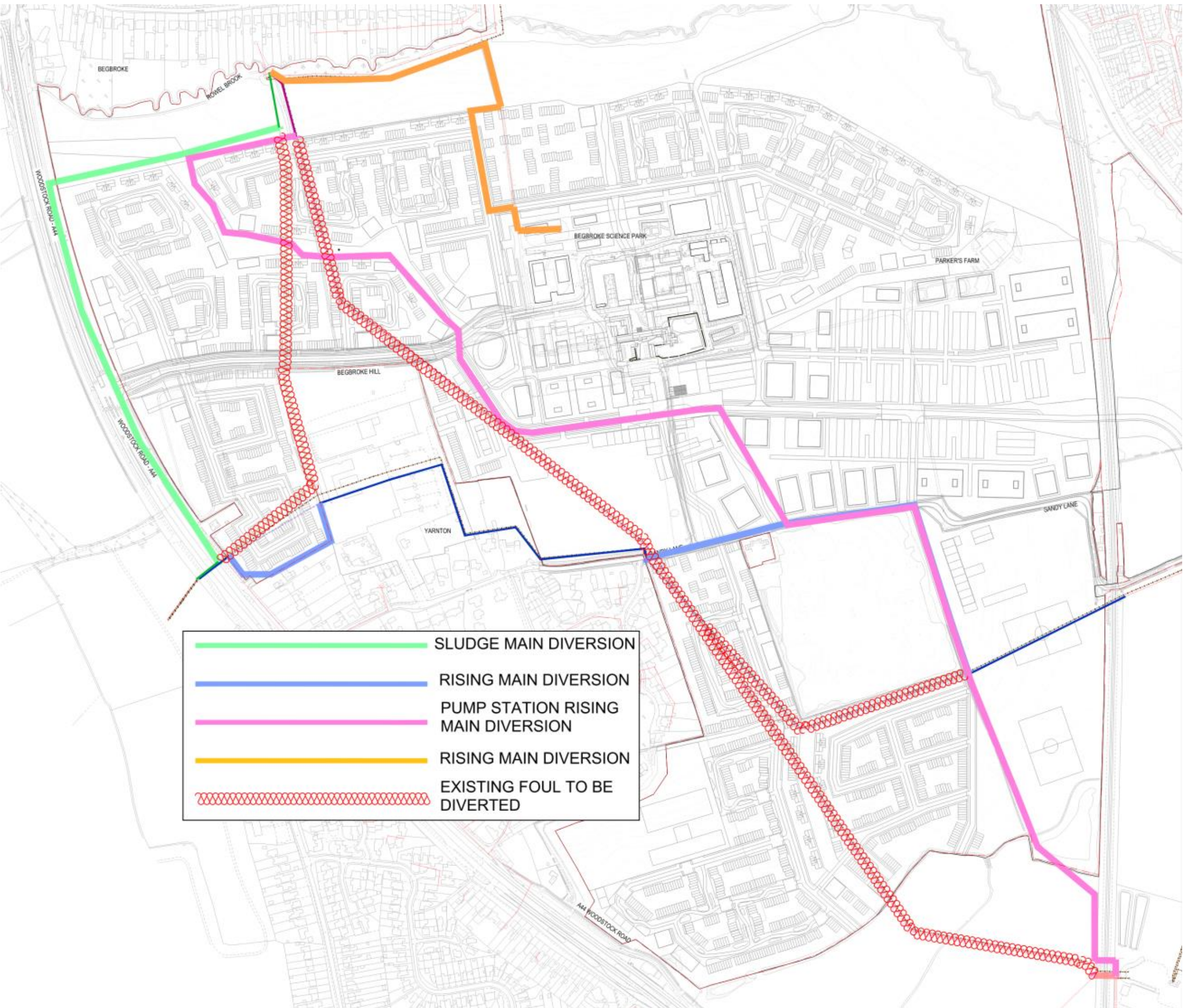


Figure 3—3 Indicative Foul Water Diversion Route Layout

Table 3—1 Foul Water Diversion Schedule

Existing Service Reference	Type of Service	Assumed Size/No. of Ducts/Pipes	Owner	Approx. Length of Diversion / Abandonment (m)
FW_RM_001	Sludge rising main	300mm ID	Thames Water	700m, 175m
FW_RM_002	Foul rising main	280mm OD (400mm under railway @ STP)	Thames Water	2,000m
FW_RM_003	Foul rising main	Unknown	Private	250m
FW_RM_004	Foul rising main	500mm OD	Thames Water	150m
FW_RM_008	Foul rising main	450mm ID	Thames Water	750m
AS_002	Abandoned Sewer	Unknown	Thames Water	750m
AS_003	Abandoned Sewer	Unknown	Thames Water	2,000m

The existing asset information shown in Table 3—1 has been compiled from Thames Water asset plans. Prior to finalising the proposed diversions, a ground penetrating radar (GPR) survey and trial pits will be undertaken to confirm exact locations.

3.3 Site Geology

The Site geology summary is based on information compiled by Hydrock through both desktop and on-Site geotechnical investigations as provided to Buro Happold in November 2022. The report produced by Hydrock is included with this drainage strategy as Appendix B.

3.3.1 Superficial Geology:

River Terrace Deposits (Summertown-Radley Sand and Gravel Member) in the central / northern plateau area of the Site at topographically high areas of the Site.

- These River Terrace Deposits in the higher central areas of the Site are considered suitable for infiltration drainage. Sufficient depth of gravel will be required above the water table. A sufficient thickness of permeable soil is required to allow for soakaways to be designed.

Alluvium in the east of the Site.

- Alluvium soils are considered unsuitable for infiltration drainage due to their high clay content (with low permeability) and the presence of a shallow ground water table.

1st River Terrace Deposits anticipated to underlie the Alluvium in the east and north and south extents of the Site.

- These thinner River Terrace Deposits at the low points of the Site are considered unsuitable for infiltration. The main cause of this is the shallow groundwater table reducing the storage capacity.

3.3.2 Solid Geology:

Oxford Clay Formation; comprising a dark grey mudstone; over

- The high clay content of this strata is considered to make it unsuitable for infiltration drainage, due to its low permeability.

Kellaways Sand Member comprising interbedded silty sand and mudstone; over

Kellaways Clay Member comprising grey mudstone; over

- The high clay content of this strata is considered to make it unsuitable for infiltration drainage, due to its low permeability.

Cornbrash Formation comprising bluish grey limestone weathering to olive or yellowish brown.

The solid strata dip gently towards the south (2° or less).

In designing surface water drainage attenuation areas in the low-lying areas of the Site, consideration has been given to the high ground water table. In these areas it is proposed that these basins be lined, or the design surface lifted to a sufficient level above the ground water level.

A more detailed summary of the geology assessment is included Hydrock's Desktop Study Review and Ground Investigation, Appendix B.

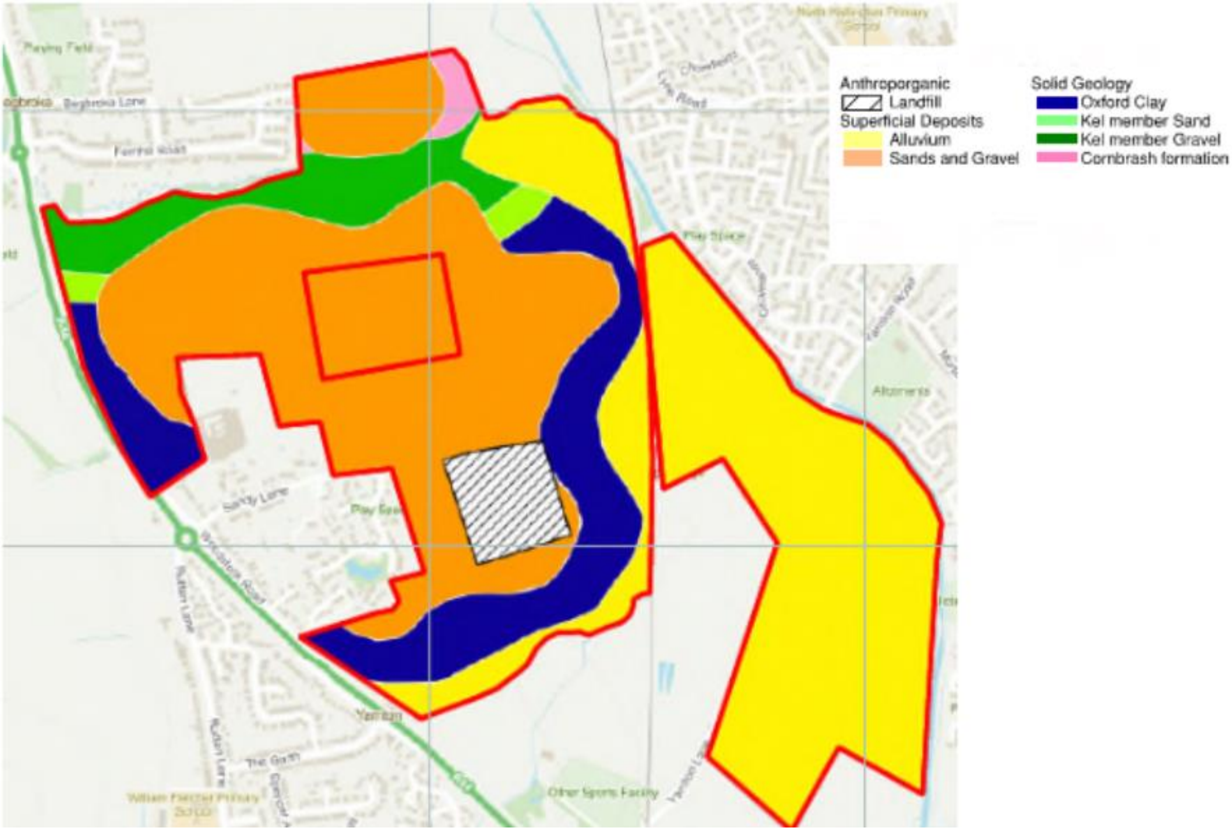


Figure 3—4 Existing Site Geology Layout (Hydrock, Appendix B)

3.3.3 Implications of Geology on Drainage Strategy

As a result of the geology observed at the Site, the drainage strategy outlined in Section 5 has been developed to best utilise areas where surface water infiltration is possible. This means maximising the volume of proposed attenuation features which are located within the 'Sands and Gravel' area highlighted in Figure 3—4. A summary of areas where there is potential for direct infiltration is shown below.

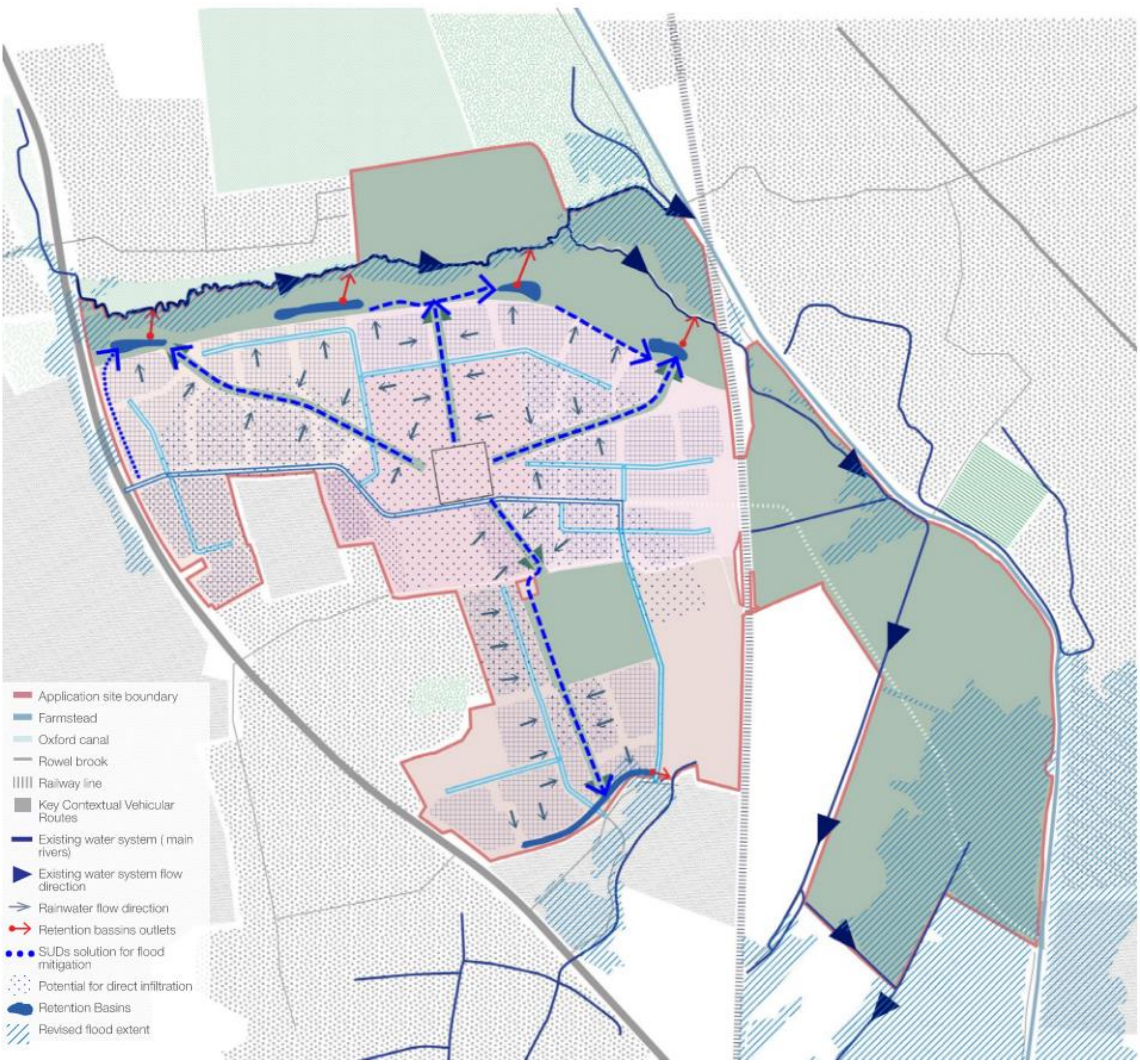


Figure 3—5 Site Wide Drainage Strategy Summary

3.4 Flood Risk Assessment

There are two locations where the Proposed Masterplan overlaps with the baseline flood extents and therefore potentially at risk of flooding without further mitigation. In the NW of the site, a swale has been proposed (Appendix G) which captures, attenuates and diverts overland flows around the development to remove the risk to the development. On the Secondary School Site, regrading has been proposed to ensure no flooding of the school site occurs. Flood storage within the red line boundary to the west of the school site is proposed to provide effective mitigation on a volume-for-volume basis so as to ensure there are no increases in flood risk outside of the red line boundary or to any development on site.

Most of the Site is subject to Very Low surface water flood risk. There are localised areas of ponding on the Site, which are classified as having Medium to High Risk of surface water flooding. These occur around the drainage channels to the south, around the east and southeast of the Site and also on the land adjacent to the Rowel Brook.

The surface water drainage strategy for the Proposed Development will aim to replicate the predevelopment surface water runoff regime. This is achieved by capturing, filtering and harvesting (where possible) surface water as close to source as possible through source control SuDS features. The SuDS hierarchy will be used to design the Site drainage in the most sustainable way. Building upon OUD’s vision for sustainable places.

All storm events up to the 1 in 100-year storm event + 40% climate change allowance are proposed to be attenuated on site and discharge from the Site to the proposed outlet at the QBAR rate. The 1 in 1-year storm event will be retained to the corresponding greenfield event. In areas of the Site where the ground conditions allow for it, infiltration is promoted to reduce the volumetric discharge of surface water from the site.

There may be a risk of groundwater flooding in the lower lying areas around the perimeter of the Site due to shallow ground water levels. This has been considered in the design of the surface water drainage strategy with regards to the location and design of attenuation ponds and use of infiltration drainage. The ground water flood risk to the Site is therefore Low.

According to the risk of flooding shown on the EA Reservoirs Map, a portion of the Site, mainly to the east/ south-east, is located within the maximum extent of flooding from reservoirs. The SFRA identifies a residual risk of flooding to the Site from overtopping of the Oxford Canal. It is noted that once the water overtops the canal in a more extreme event, this will have been captured in the fluvial flood modelling and therefore risk mitigated against if required for the development. The overall flood risk from artificial sources is Low and no further mitigation is required.

It is concluded that with the mitigation measures outlined within the Flood Risk Assessment accompanying this report (BEG-BUR-XX-XX-RP-XX-00001-FRA), the Proposed Development is at Low risk of flooding from all sources.

4 Consultation

4.1 Oxford County Council-Local Lead Flood Authority (OCC LLFA)

In developing this strategy Buro Happold have been in consultation with OCC LLFA and the overarching principles and the key engineering constraints have been agreed. Buro Happold has created a outline surface water drainage model based on the initial QBAR runoff rates, which are a conservative flow rate. The existing QBAR runoff rates being used as the basis of design provide the optimal discharge conditions from the Site. These are to be confirmed with the LLFA in a meeting on the 5th of June, 2023. By using this QBAR rate and the proposed illustrative masterplan as a proxy for what the future development will look like, the required attenuation volume for the Site was calculated. Meeting minutes for the Stage 1 and Stage 2 LLFA coordination meetings can be found in Appendix C.

Further meetings will be held with the LLFA when the project enters the detailed design stages to show how the design is meeting the agreed design principles.

4.2 Environment Agency

The EA were contacted in the formation stage of the drainage strategy via email for input. On the 5th of October 2022 the EA advised that they are not the responsible authority for surface water flood risk and that no further consultation is required with them.

4.3 Thames Water

A pre-development application has been lodged with TW (Ref: DS6099943). For connection to TW's foul water network TW have advised that a connection into the existing foul water pumping station on the northern boundary of the Site is not possible, but that there is an opportunity to connect the existing manhole (TW Ref: 4804) upstream of it. This is the current proposed point of connection for the Phase 1 area of development in the north. Phase 2 – 4 is currently proposed to connect through a utility culvert in the southeast of the Site to an existing manhole to the north of Kidlington Lane (Ref: 5402).

For connection to TW's potable water network, point of connection (REF DS6099942) was received on the 08/03/23 and attached as Appendix E.

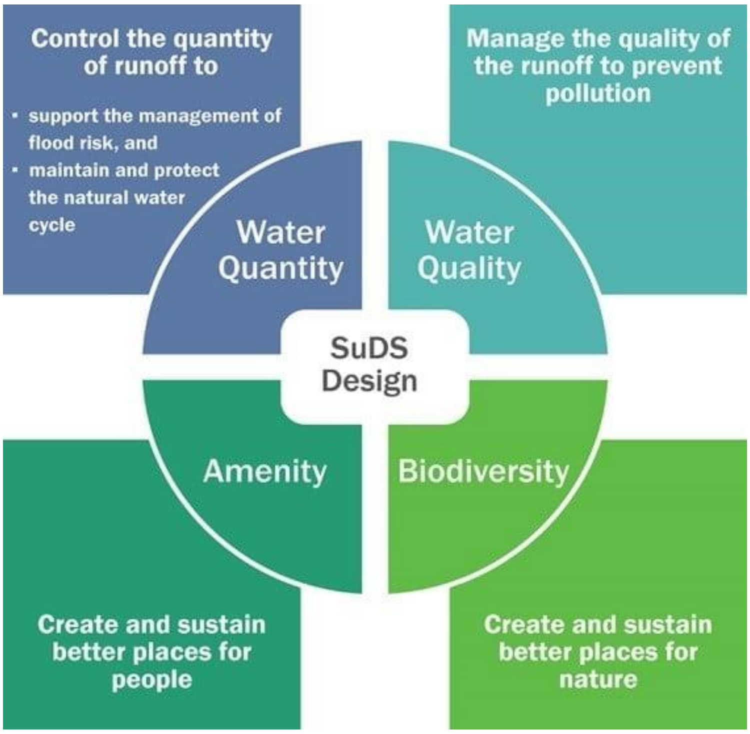
5 Proposed Surface Water Drainage

5.1 Basis of Design

5.1.1 Sustainable Drainage Systems (SuDS) Hierarchy

In developing the surface water strategy for the Proposed Development, the following design hierarchy and principles have been adopted:

1. Store rainwater for later use
2. Use infiltration techniques, such as porous surfaces in non-clay areas
3. Attenuate rainwater in basins or open water features for gradual release
4. Attenuate rainwater by storing in tanks or sealed water features for gradual release
5. Discharge rainwater direct to a watercourse
6. Discharge rainwater to a surface water sewer/drain
7. Discharge rainwater to the combined sewer



The aim should be to discharge surface run off as high up the hierarchy of drainage options as reasonably practicable.

5.1.2 Water Quality

With the above hierarchy in mind, the capture and treatment of surface water within a development is often referred to as a 'treatment train' where water slowly flows from where it falls to a watercourse through a series of features that help treat, store and re-use, convey and provide amenity and biodiversity value. By passing water through several stages of treatment, sediment and other pollutants will be removed more effectively.

5.1.3 Storm Events

All storm events up to the 1 in 100-year storm event + 40% climate change allowance are proposed to be attenuated on site and discharge from the Site to the proposed outlet at the QBAR runoff rate. The 1 in 1-year storm event will be retained to the corresponding greenfield event. In areas of the Site where the ground conditions allow for it, infiltration is promoted to reduce the volumetric discharge of surface water from the Site.

5.2 Site Wide Strategy

The proposed drainage strategy and SUDs infrastructure proposed varies based on two lands uses within the development, residential and commercial. The below flow charts outline the proposed surface water drainage strategy in each instance. In both instances the priority is to prioritise SuDS infrastructure over traditional pit and pipe drainage infrastructure.

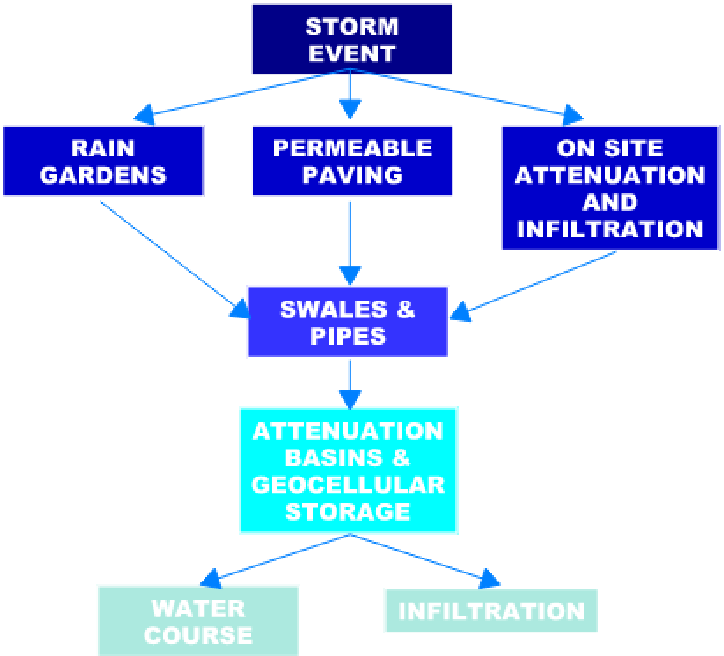


Figure 5—1 Storm events falling on Residential areas

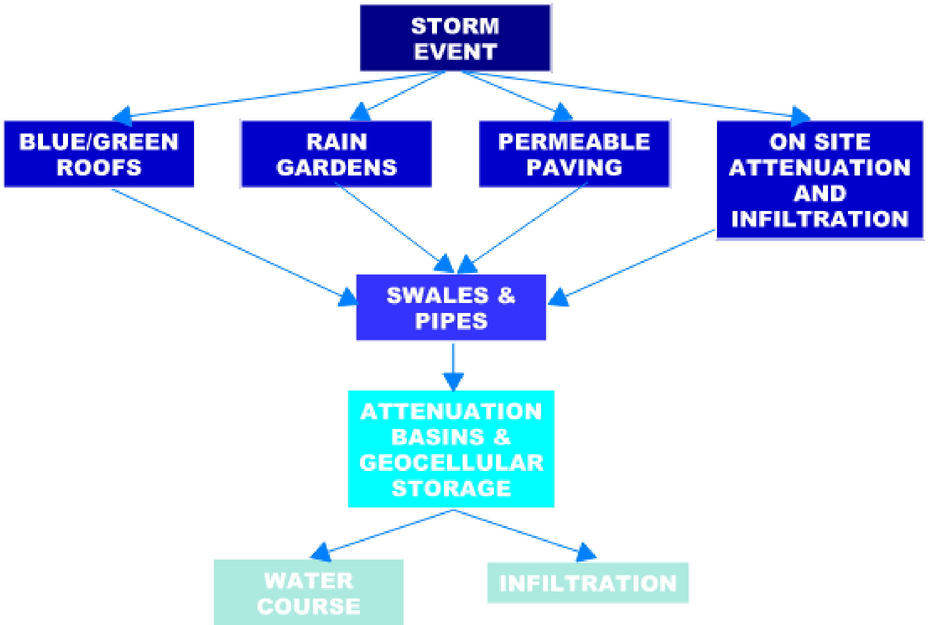


Figure 5—2 Storm events falling on Commercial areas

5.3 Proposed SUDs Features

Table 5—1 Summary of Proposed SUDs Features

	SUDs Feature	Land Type	Source / Site Control	Summary & Benefit
1	Blue/Green Roofs	Commercial	Source	Blue/Green roods restrict the rate that water runs off from a building into storm drains or natural watercourses after a downpour, thus minimising the impact on water quality, biodiversity, and flooding.
2	Rain Gardens	Commercial/ Residential	Site	Rain gardens are small, landscaped depressions that can reduce runoff rates and volumes, whilst providing a form of treatment by filtering the runoff through engineered soils and vegetation.
3	Permeable Paving	Commercial/ Residential	Source	Water is then attenuated in a sub-base aggregate where it is infiltrated and slowly discharged into the next stage within the drainage system.
4	Attenuation Basins	Commercial/ Residential	Site	Dry, landscaped depressions that allow for attenuation, treatment via settling and infiltration of stormwater flows. These basins will only hold water immediately after storm events, prior to it being evaporated and infiltrated. Where the ground conditions permit, these basins will allow infiltration of attenuated flows.

5	Swales	Commercial/ Residential	Site	Linear strips which are vegetated/grassed and can be designed to allow storage of surface water during storm events and infiltration along their length. Since they promote low flow velocities, they are effective in allowing suspended particulates to settle-out thereby removing pollutants from surface water run-off.
6	Geocellular Storage	Commercial/ Residential	Site	Cellular crates that provide an underground storage structure with high void ratio that is suitable for attenuating surface water flows. The flows can be released either into the in-situ ground through infiltration (ground conditions permitting).

5.4 Attenuation Basin Preliminary Sizing

5.4.1 Design Criteria

The surface water attenuation basins should be designed in accordance with The SuDS Manual (C753) guidance produced by CIRIA.

The key design criteria include:

- Upstream pre-treatment to remove sediment and silt loads to prevent long term clogging;
- Maximum depth of water should not exceed 3m in the most extreme design event;
- Retention basins will be designed to store the 1 in 100 year storm event.
- Further detail will be provided at the detailed design stage.

5.4.2 Site Wide Catchments

The outline surface water drainage strategy aims to respect the existing catchments and attenuate surface water close to its source before discharging into the three local watercourses. The assessment carried out is an indicative one based on the information at hand at the time of publishing. It is seen as a reasonable way to gain an understanding of the site conditions at this early stage of design development.

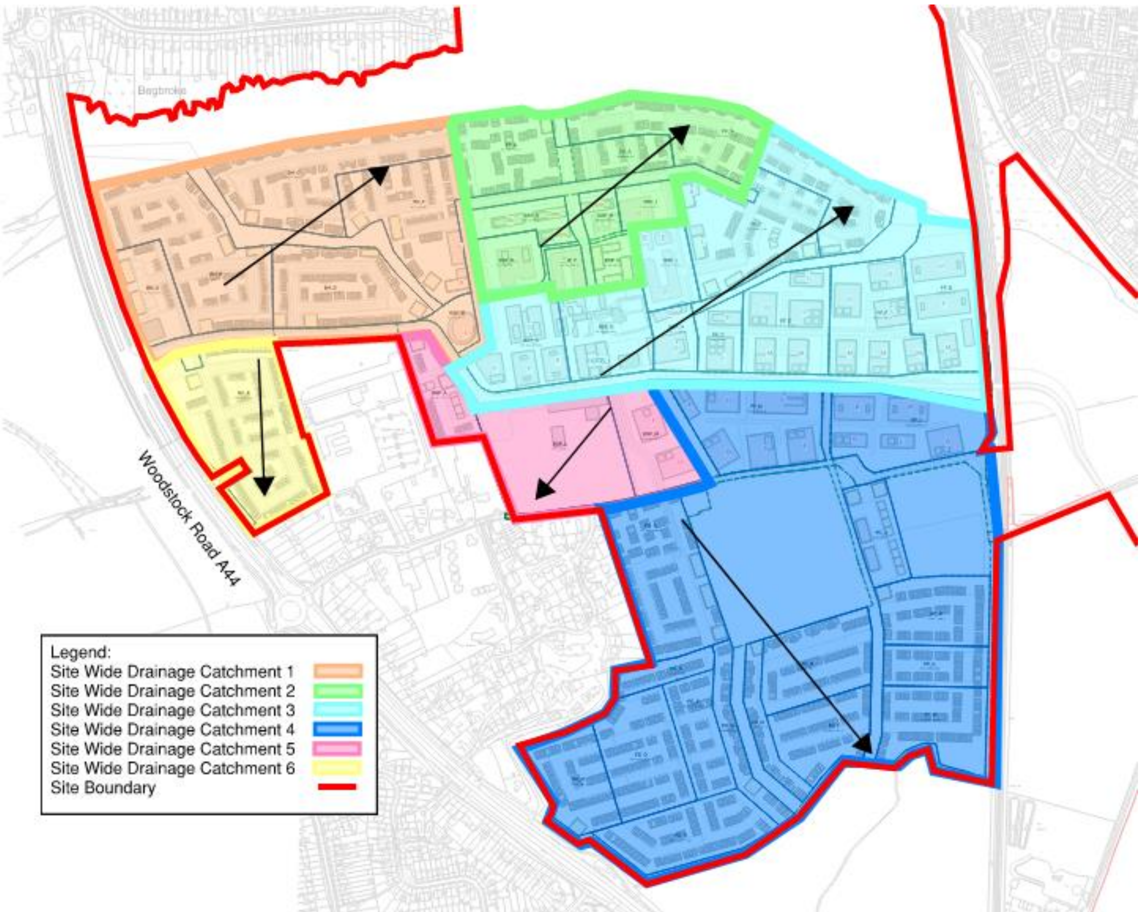


Figure 5—3 Overall Site drainage catchments

5.4.3 Existing Runoff Assessment

5.4.3.1 Runoff Rate Assessment

The existing catchment greenfield runoff and QBAR rates for catchments within the Site have been calculated from the rates shown in flood modelling report carried out by Eden Vale Young Appendix D. This report additionally details how surface water flows from outside of the catchment are captured and directed to the agreed outlets prior to entering the development network.

Table 5—2 Existing Catchment Greenfield Runoff Rate Summary

Existing Catchment	Catchment Area (Ha)	1 in 2 yr (l/s)	1 in 30 yr (l/s)	1 in 100 yr (l/s)	1 in 100 yr +40% CC (l/s)	QBAR (l/s)	Point of Discharge
E1	17	10.5	25.6	34.7	48.5	11.3	Rowel Brook Discharge Point 1 +Infiltration
E2	10	7.3	15.9	21.5	30.2	7.1	Rowel Brook Discharge Point 2
E3	21	25.1	51.6	69.6	97.4	22.6	Rowel Brook Discharge Point 3+Infiltration
E4	38	59.1	137.7	185.4	259.6	59.9	Existing unnamed watercourse (ditch)+Infiltration

E5	6	5.1	12.5	16.9	23.7	5.5	Infiltration
E6	5	3	7.3	9.9	13.8	3.2	Infiltration

*As per LLFA guidance – The discharge rates for all storms up to the 1 in 100-year storm event will be limited to the QBAR rate (or 2l/s/ha whichever is greater) – Given the early stage of design BH is using the more conservative QBAR values above rather than 2l/s/ha, with the understanding that this may change as the design develops.

5.4.3.2 Runoff Volume Assessment

The parameters listed below were used in the design of the drainage strategy:

- Storage volumes calculated based on 1 in 100 + CC storm events, dependent on availability of space to store 1 in 100 + CC either above and/or below ground
- Climate Change: 40% (based on EA current guidance)
  - FEH Rainfall Data
- Factor of Safety for infiltration = 2
- Assumed infiltration rate based on current data = 0.000167m/s (The median value of infiltration rates outlines in Appendix B)
- The current masterplan layout (BEG-HBA-SW-ZZ-SK-A-SK02, received on the 11th May) has been assessed with an estimated percentage of impermeable surface (PIMP%) calculated for each of the sub-catchments within Catchment 1. The PIMP% has been based on 3 No. different land area types – rooves, pavements and green/soft spaces, each carrying different volumetric runoff coefficients. Using the methodology outlined in **Error! Reference source not found.** , the following PIMP% were calculated for each of the 3 sub-catchments within Phase 1:
  - Western Network = 50%
  - Central Network = 50%
  - Eastern Network = 54%.

Table 5—3 PIMP% Calculation Summary

Western Network	**Area (ha)**	**Volumetric Runoff Coefficient**	
Roof	1.0	0.95	
Pavement	1.0	0.9	
Permeable	1.7	0[1]	
Total	3.7		
Combined PIMP%	= (1.0*0.95+1.0*0.9+1.7*0)/3.7 = 50%		
Central Network		**Area**	**Volumetric Runoff Coefficient**
• Roof		1.8	0.95
• Pavement		1.7	0.9
• Permeable		3.0	0[1]
Total	6.5		

Combined PIMP%	= (1.8*0.95+1.7*0.9+3.0*0)/6.5 = 50%	
• **Eastern Network**	**Area**	**Volumetric Runoff Coefficient**
Roof	1.6	0.95
Pavement	1.5	0.9
Permeable	2.2	0[1]
Total	5.3	
Combined PIMP%	= (1.6*0.95+1.5*0.9+2.2*0)/5.3 = 54%	
Notes: 1. A volumetric runoff coefficient of 0 has been used for permeable areas based on assessment of the greenfield runoff rate and the fixed runoff equation.		

- Conservative Cv values of 0.89 (Summer) and 1 (Winter) have been used for the attenuation volume assessment outlined in Section **Error! Reference source not found.**.

5.4.4 Required Attenuation Assessment

Table 5—4 Proposed attenuation requirement for 1:100 yr event+40% cc Storm Event

Proposed Catchments	Proposed Catchment Area (ha)	Maximum Allowable Discharge QBAR Rate (l/s)	Required Attenuation Range (m^3)
Pr1	17	**11.3**	1254-5701
Pr2	10	**7.1**	738-3353
Pr3	21	**22.6**	1446-7014
Pr4	38	**59.9**	2409-12635
Pr5	6	0 (GeoCell Infiltration proposed)	444-2019
Pr6	5	0 (GeoCell Infiltration proposed)	370-1682

The flood risk assessment BEG-BUR-XX-XX-RP-XX-00001-FRA, document provided as part of this submission details the proposed strategy in capturing and discharging overland flow from the proposed secondary school site. This is to remove flooding from the Site, in line with OCC guidance.

In order to reduce the required size of attenuation features as well as pipe diameters and swale widths within the surface water network, it is proposed that plot developers attenuate flows within their development, to a specified controlled discharge rate. The system aims to ensure that any attenuation required within the plots I kept to a minimum. This could be achieved through the construction of basins within the plots or other measures such as blue roofs being incorporated into building construction within commercial areas.

Considering the results gained from site investigation to date detailed in Appendix B, promoting infiltration is deemed to be advantageous in areas upstream of the catchment outlets. This is where a deeper ground water level and greater achievable infiltration rates are present.

5.5 Proposed Surface Water Drainage Network Layout

5.5.1 Site Wide

The Site wide surface water network will follow the existing site topography and natural flow channels to existing discharge points as far as practically possible. Key features of the Site topography include:

- BSP sits at the highest point of the Site. The surrounding land falls away in all directions towards low points at Rowel Brook, Hallam Land and the Network Rail boundary.
- Sandy Lane forms an east-west topographical ridge which intercepts surface water flowing north-south.

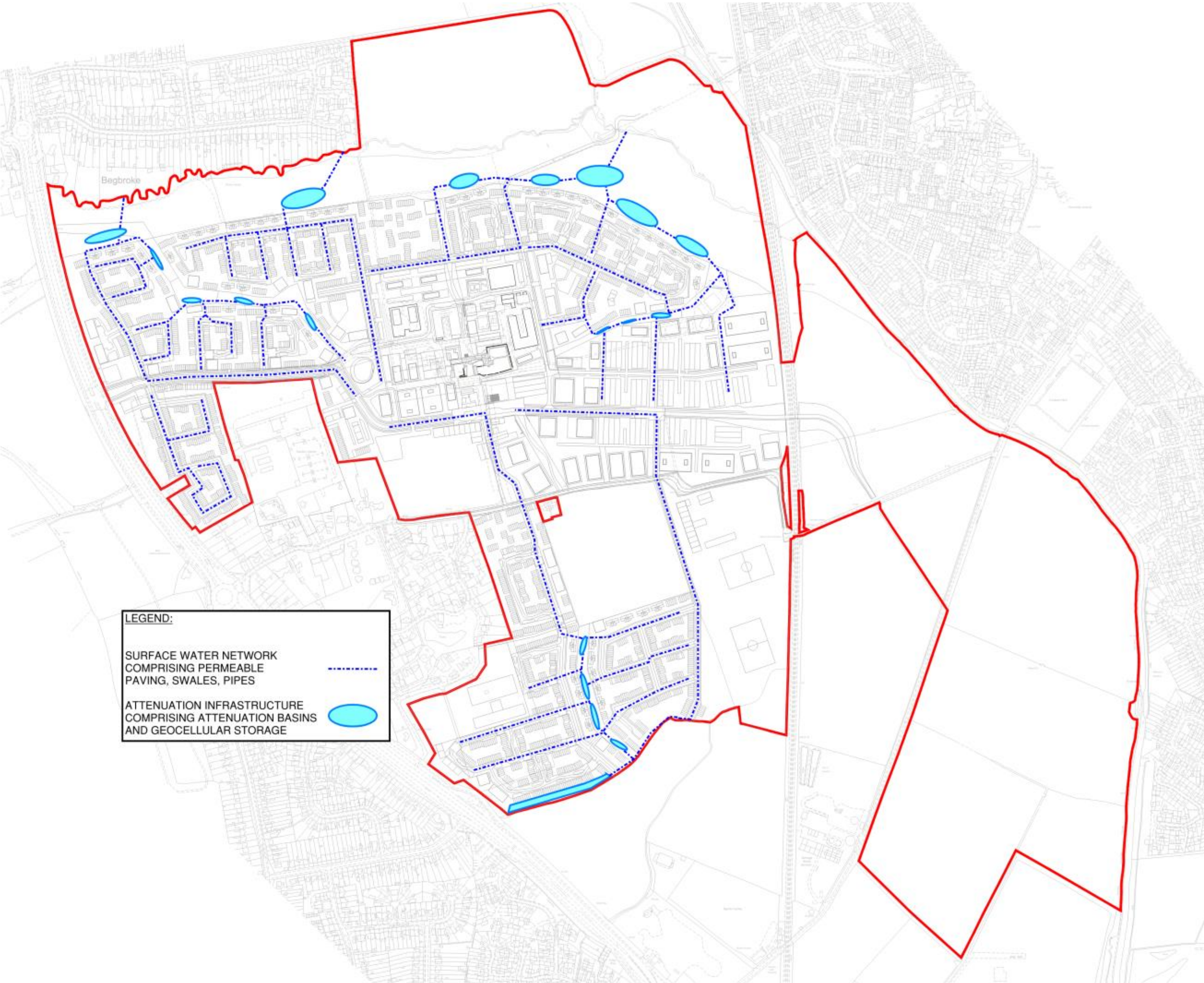


Figure 5—4 Schematic Site Wide Drainage Layout

For the purposes of this assessment, indicative modelling of a surface water network has been carried out for the north-western part of the Site. This corresponds with surface water catchment 1, shown in **Error! Reference source not found.**. It is anticipated that the key concepts of the indicative Catchment 1 surface water design and network would be mirrored across the rest of the Site.

5.5.2 Catchment 1

The illustrative network within the Catchment 1 has been split into 3 sub-networks, with each having varying outfall locations and constraints. The conveyance of surface water through the sub-networks follow the SuDS hierarchy outlined in Section **Error! Reference source not found.** and is briefly summarised below:

5.5.2.1 Western Portion of Catchment 1

The western network collects surface water flows from the western plots, the road catchment within these plots and part of the landscaped corridor ('green spine') bisecting the catchment. From collection through source and site control features outlined in Table 5—1 Summary of Proposed SUDs Features, flows are conveyed via a concrete pipe network into one of 3 No. attenuation basins, located along the northern extent of the development and within the green spine. Infiltration has not been allowed for in the locality of these basins due to a high groundwater table and high clay content of underlying soils. Surface water is attenuated within these basins and then discharged at the controlled rate outline in **Error! Reference source not found.**, via the use of a Hydrobrake or similar flow control device, into Rowel Brook through a proposed DN300 pipe outfall (West Outfall).

5.5.2.2 Central Portion of Catchment 1

The central network collects surface water flows from plots in the elevated middle area of the catchment, Begbroke Hill and the remainder of the green spine not captured by the western catchment. Flows are then conveyed in the same manner as the western network into 5 No. infiltration basins, 2 No. of which include subsurface geocellular storage.

With a moderately deep groundwater table and gravels present in this area of the catchment, it is intended that infiltration to ground be utilised to the full extent possible. Each of the basins and geocellular storage will act to soakaway surface water such that no onwards discharge to Rowel Brook is required from the central network. For redundancy, an emergency overland flow channel has been allowed for connecting the central network into the western network and discharge into Rowel Brook in extreme events (exceeding 1 in 100 year + 40% cc).

5.5.2.3 Eastern Portion of Catchment 1

The eastern network collects surface water flows from eastern plots and the road catchment within these plots. From collection, the flow conveyance methods as described in the western network is mimicked, before discharge 1 No. attenuation basin located near the north east boundary of the Catchment 1 area. Infiltration has not been allowed for in the locality of the eastern network basin due to moderately-high groundwater table and high clay content of underlying soils. Surface water is attenuated within this single basin and then discharged at the controlled rate outlined in **Error! Reference source not found.**, via the use of a Hydrobrake or similar flow control device, into Rowel Brook through a proposed DN300 pipe outfall (East Outfall).

5.5.3 Network Design Criteria

It is proposed that the SWD Strategy will adhere to the following design criteria in accordance with the relevant guidance wherever it is deemed reasonably practicable, an assessment that is ongoing.

5.5.3.1 Peak Flow Control

Limit discharge rates for rainfall events up to and including the 1 in 100-year event (including climate change allowances) to the agreed QBAR rate (or 2l/s/ha whichever is greater) and 1 in 1 year event to the corresponding green field event.

5.5.3.2 Volume Control

Where reasonably practicable, for greenfield runoff development, the runoff volume from the development to any highway drain sewer or surface waterbody in the 1 in 100-year, 6-hour rainfall event should never exceed the greenfield runoff volume for the same event.

5.5.3.3 Flood Risk within the development

Surface water will be confined to the drainage system in a 1 in 30-year (+25% CC) rainfall event.

- The proposed buildings on site will be protected from flooding in the 1 in 100-year (+40% CC) events.

Exceedance in the 1 in 100-year rainfall events is to be managed in exceedance routes that minimise the risks to people and property.

The flood risk assessment carried out by Buro Happold in May 2023 indicated that at maximum flood levels, the 2 No. proposed surface water outfalls would both be submerged by approximately 0.7m of water. These levels have been incorporated into the Microdrainage Surface Water model when assessing the design. The preliminary modelling carried out on the proposed drainage strategy demonstrates that no upstream flooding caused by raised water levels of Rowell Brook.

6 Proposed Foul Water Drainage

6.1 Thames Water Engagement

Thames Water has been consulted on the discharge of the proposed development to the local sewer system. A pre-development enquiry was submitted on the 25th October (TW Ref DS6099943) for a connection based on the load estimation calculated. A follow up in person meeting was held at TW offices on the 30th of January. It is proposed that a connection will be made to the 300mm pipe connecting to the pumping station adjacent to the north west of the Site for the northern area of the Site and a pumping station will be required in the south of the Site to pump to the proposed discharge point south of the Site east of the railway.

The foul water drainage strategy has been developed around the below key proposals:

1. Northern Point of Connection

It is proposed that the north of the Site utilises the existing TW pumping station and rising mains that cross the south from the northwest to the southeast. The north of the Site will connect to TW manhole 4804. These flows will then be conveyed through the existing pump station to the southeast of the Site, where the existing rising main connects to an existing 600mm gravity TW main at TW manhole 5402. Preliminary design of this network suggests that 2 No. pumping stations will be required to achieve connection into TW manhole 4804.

2. Southern Point of Connection

It is proposed that the foul water flows from the south of the Site will connect to the TW network at TW manhole 5402. An initial engagement with TW has occurred regarding the use of the existing utility culvert under the railway. It is anticipated that a minimum of one pumping station will be required to achieve this connection.

6.2 Foul Water Load Estimation

The foul water load estimates are detailed below in Table 6—1.

Table 6—1 Peak Foul Water Flow Estimate by Typology Based on Potable Water Demand

Typology	Units (No.) / Area (m2)	People	Benchmark *Sewers for Adoption 'The Code' & Urban Drainage – Butler & Davis.*	Average Daily Demand AADD (l/s)	Peaking Factor *Urban Drainage – Butler & Davis.*	Infiltration	Total Peak Hourly Demand (l/s)
Residential	1800 No.*	NA	0.05 l/s/dwelling	NA	NA	10%	99.00
Faculty (16% of combined area from use schedule)	24,800 m2	NA	0.6 l/s/ha	1.488	6.00	10%	8.928
Commercial (84% of combined area	130,200 m2	NA	0.6 l/s/ha	7.812	6.00	10%	46.872

Typology	**Units (No.) / Area (m2)**	**People**	**Benchmark** ***Sewers for Adoption 'The Code' & Urban Drainage – Butler & Davis.***	**Average Daily Demand AADD (l/s)**	**Peaking Factor** ***Urban Drainage – Butler & Davis.***	**Infiltration**	**Total Peak Hourly Demand (l/s)**
from use schedule)							
Primary School 2FE (Pupils)	NA	640	100 l/pers/day	0.74	6.00	10%	4.44
Secondary School 6FE (Pupils)	NA	900	100 l/pers/day	1.042	6.00	10%	6.34
Public Real, Retail & Community Uses	2,000	NA	10 l/pers/day	2.79	6.00	10%	16.73
Total Development Potable Water Demand							**181.87**

*This is based on the assumption that the 215,000sqm GEA of residential floorspace would equate to 1,800 homes.

6.3 Foul Water Drainage Network

The foul water network is split by development area and will utilise gravity pipework as well as lift pump stations and rising mains, where necessary to convey flows to the proposed point of connection (POC).

Development in the north of the Site is proposed to connect to the Thames Water existing manhole 4804 to the immediate east of the existing pump station adjacent to Rowell Brook. To connect the remainder of the site to the network there is a second proposed pump station in the southeast of the Site.

Given the limited number of alternative discharge options and relative cost effectiveness, it is believed that this proposal for discharge to the existing Thames Water network is the most beneficial solution. Flows from the existing pump station are then conveyed via a rising main to the southeast corner of the Site where they will converge with flows from the proposed pump station in this area. From here, the foul water will pass beneath the Network Rail line via a proposed rising main and discharge into the existing gravity system.

The capacity of the existing pump station and rising main is critical to the function of the proposed network. As such, confirmation from Thames Water on the capacity of this infrastructure has been requested. TW have advised of approval to connect to their existing northern pump station.

At this stage of design, it is estimated that gravity pipework no larger than 300mm diameter will be required to sufficiently convey foul water flows to their required connection points - based on network modelling in Microdrainage. Sizing of the infrastructure for the proposed pump stations and rising main will be carried out during the detailed stages of design.

All sewerage assets would be designed in line with the design criteria set out in the Water UK Design and Construction for Foul and Surface Water Sewers Industry Guidance (The Code). The network would be put forward for adoption by Thames Water under Section 104 of the Water Industry Act 1991.

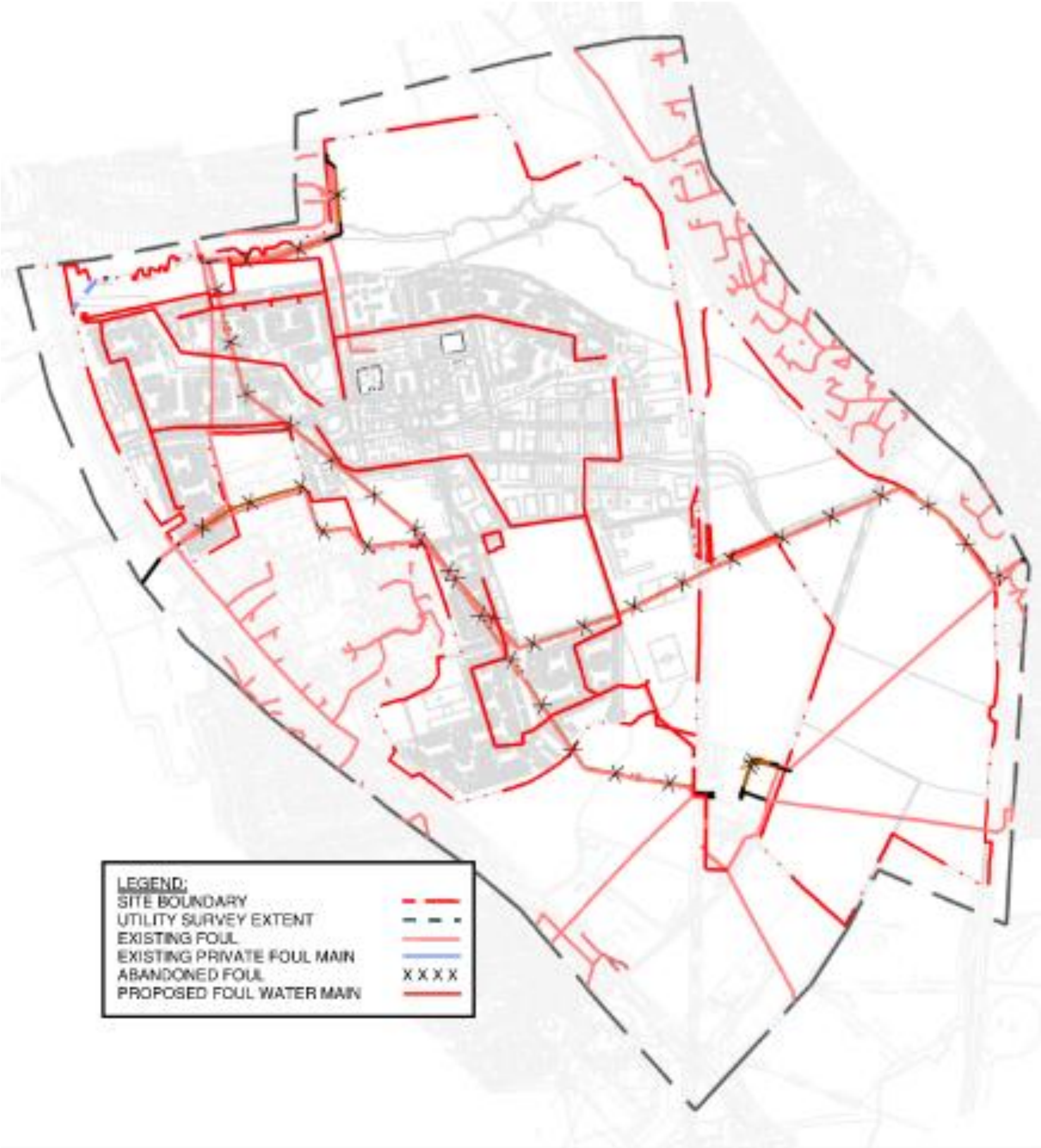


Figure 6—1 Indicative Sitewide Foul Water network layout

6.4 Foul Water Adoptable Pumping Station

The typical layout of an adoptable Type 3 pumping station is defined in the Water UK Design and Construction industry guidance. This requires an approximate 8m x 12m land take that allows access for a tanker. The typical layout, taken from The Code can be seen overleaf. It is assumed that the compound will require fencing to prevent unauthorised access. The compound is required to accommodate the inlet manhole, pump wet well chamber and the valve chamber. A kiosk for operation of the pump will also be required. Most of the plant within the compound will be located below ground, with the kiosk being presented above ground.

As per Thames Water's Local Practices to Support Code for Adoption Sewerage document, a minimum of 4 hours of emergency storage will be provided at all of the proposed foul water pump stations.

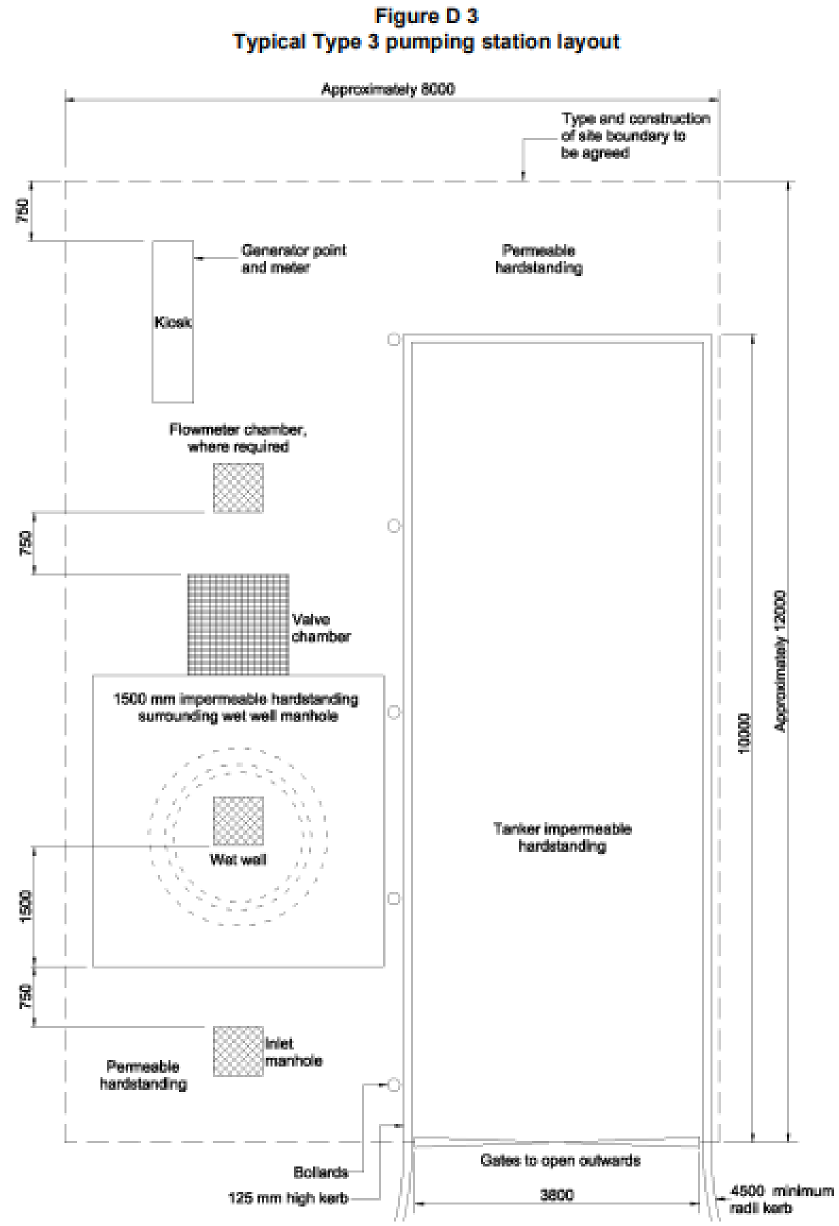


Figure 6—2 Typical Pumping Station Detail (The Code V2.0, 2020)

7 Summary and Conclusion

This drainage strategy has been carried out on behalf of OUD as part of the Outline Planning Application for the proposed mixed-use development on the current site of Begbroke Science Park, Begbroke, Kidlington. The Proposed Development consists of the expansion of the existing Science Park, residential and associated amenity, education and community uses.

The surface water drainage strategy for the proposed development will aim to replicate the predevelopment surface water runoff regime. This is achieved by capturing, filtering and harvesting (where possible) surface water as close to source as possible through source control SuDS features. The SuDS hierarchy will be used to design the Site drainage in the most sustainable way, building upon OUD’s vision for sustainable places. Wherever possible, SuDS features will be specified over traditional piped drainage to maximise water quality benefits and site amenity.

The foul water strategy is split by development area and will utilise gravity pipework as well as lift pump stations and rising mains, where necessary to convey flows to the proposed points of connection (POC). For the north western part of the site, the proposed POC is Thames Water existing manhole 4804 to the immediate east of the existing pump station in the north of the Site. Flows from the existing pump station are then conveyed via a rising main to the southeast corner of the Site where they will converge with flows from the rest of the site at another proposed pump station in this area.

For the southern section of the site flows will be conveyed to this proposed south eastern pump station via gravity pipework. From here, the foul water will pass beneath the Network Rail line via a proposed rising main and discharge into the existing gravity system.

The information provided in this drainage strategy will be used to in inform more detailed design proposals as the project develops.

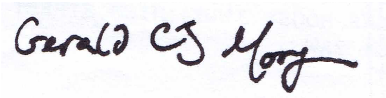
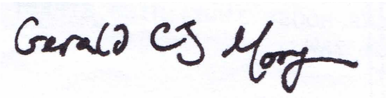
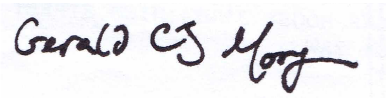
Appendix F Proposed Secondary School Site Hydraulic Modelling Technical Note

MAY 30TH 2023

Proposed School Site Modelling

Project Name Begbroke Innovation District
Project Number EVY1077
Prepared For Buro Happold

Document Control

Written by	 Dr. Gerald C J Morgan	May 30th 2023
Checked by	 Dr. Gerald C J Morgan	May 30th 2023
Approved by	 Dr. Gerald C J Morgan	May 30th 2023

Revision	Issued to	Date
A	Buro Happold	May 30, 2023

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1. Introduction

1.1 Project Requirements

Edenvale Young Associates have been commissioned by Buro Happold to undertake hydraulic modelling at a site west of Kidlington, Oxfordshire. The results of this hydraulic modelling will be used to inform a Flood Risk Assessment (FRA) for the proposed Begbroke Innovation District—a mixed use development incorporating the existing Begbroke Science Park.

The Begbroke Innovation District incorporates a proposed school site and it is a project requirement that this school site be free of flooding in the design flood events. Accordingly it is proposed to re-grade the land within the school site so that flood risk from outside that land is eliminated and to manage the rainfall incident on the site via surface water drainage.

1.2 Purpose of this Note

This technical note outlines the results of hydraulic modelling work to assess the impacts associated with re-grading the school site. The location of the school site is shown in figure 1.1.

This note will not recapitulate the baseline hydraulic modelling and should be read in conjunction with the main hydraulic modelling report, "Hydraulic Modelling Report - Begbroke Innvoation District" revision B.

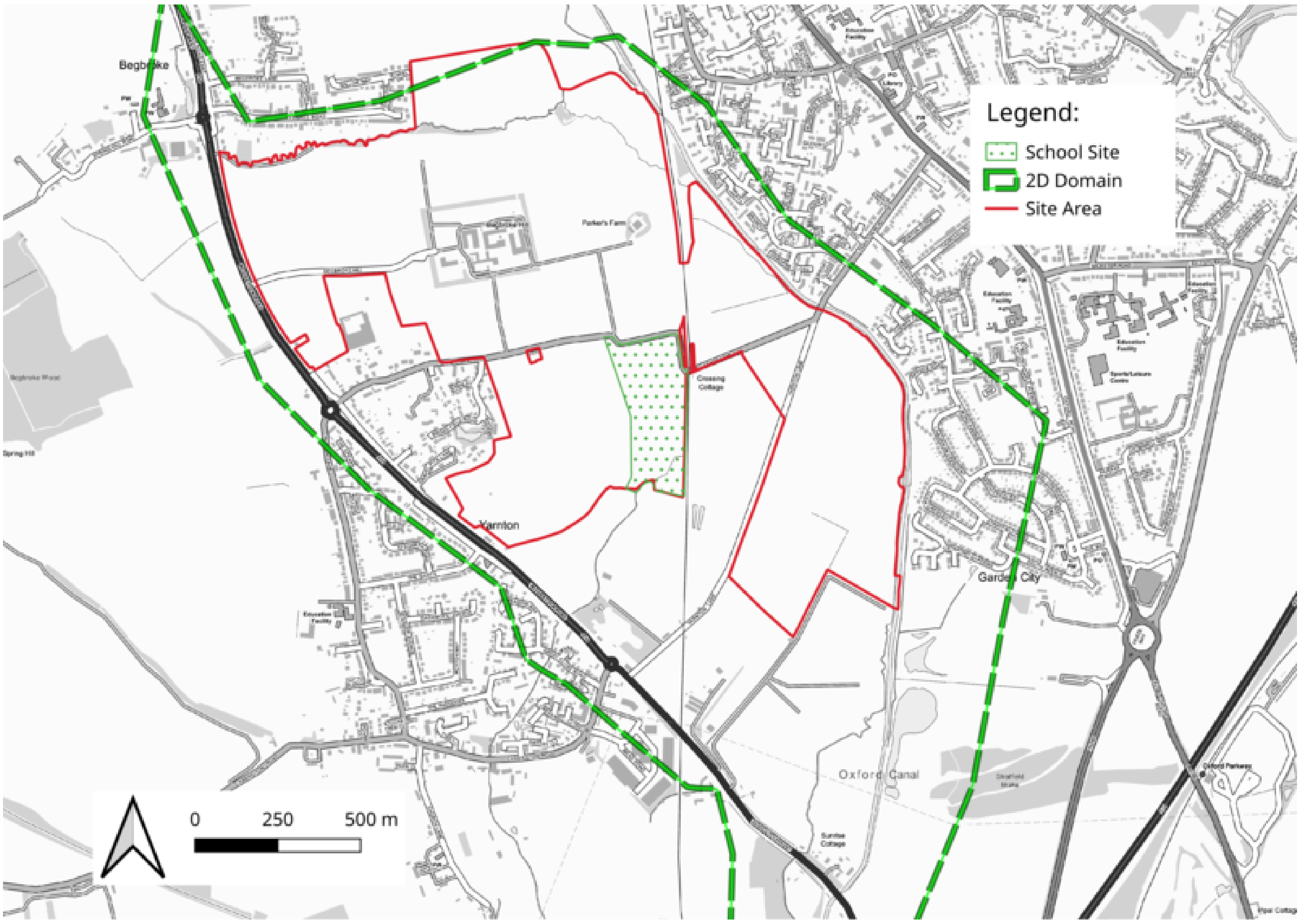

Figure 1.1: *School site location within the wider Begbroke Innvoation District red line.*

2. Hydraulic Modelling

2.1 Baseline Modelling

The latest version of the baseline model as described in revision B of "Hydraulic Modelling Report - Begbroke Innovation District" has been used. The effect of the re-grading has been modelled for three design events: two 1% AEP events with 26% and 41% allowance for climate change (the "Central" and "Higher" estimates for the 2080s epoch, respectively); and the 0.1% AEP "present day" event. An 11-hour storm duration has been used in each case.

2.2 Land Raising

It is proposed to re-grade the school site by raising the ground levels sufficiently to prevent flood water backing up onto the site from the southern drainage ditch. In the model, the school site has been raised to a level above the highest modelled flood levels and the hydrological inflow location for the southern drainage ditch has been moved downstream to the edge of the school site. These model changes are representative of the proposed works under the following assumptions:

- The proposed grading of the school site does not significantly alter the drainage directions of ground and surface water, which continues to drain from the existing catchments to the southern drainage ditch.
- The reaches of the southern drainage ditch currently crossing the school site are backfilled as part of the re-grading process.
- Excess rainfall on the school site is handled by the surface water drainage system and drains to the southern drainage ditch at approximately green-field run-off rates.

2.3 Connectivity

The proposed land-raising across the school site would necessitate the filling-in of an existing tributary reach of the southern drainage ditch across the southwest corner of the site. This would severely limit connectivity with this area and is likely to cause significant downstream disbenefit. Accordingly, a replacement channel is proposed along the boundary of the school site to maintain the connectivity of the southern drainage ditch. The route of this channel is shown in figure 2.1. This has been simulated through land-lowering in the 2D model. It should be noted that, as the existing ditch falls within the school site, it is assumed to be backfilled and the replacement channel will follow the boundary of the site, to the southwest.

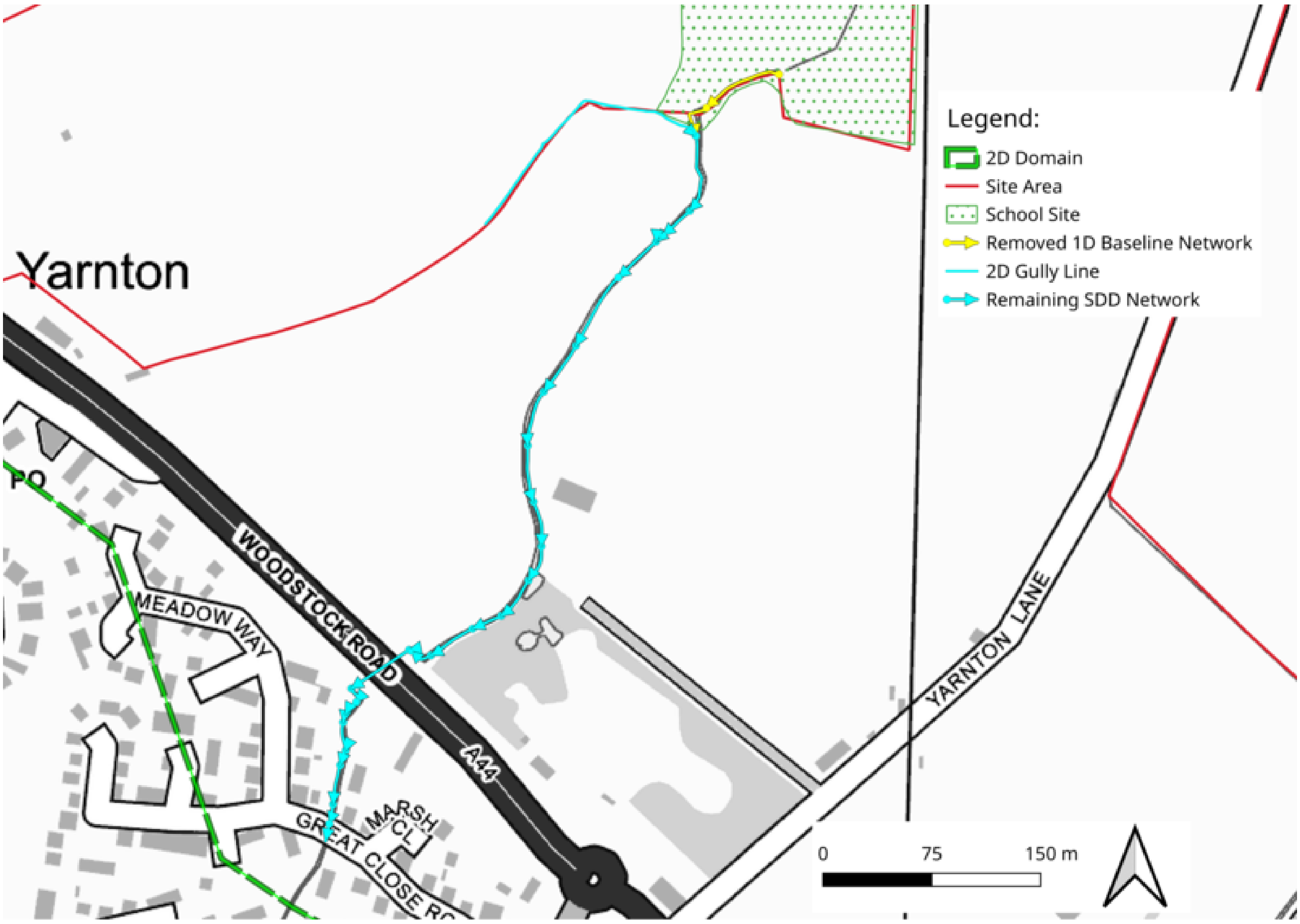

Figure 2.1: *Plan showing changes between the baseline channel schematisation and the proposed condition.*

EdenvaleYoung

3. Results

Maximum Depth

Figures 3.1–3.3 show the maximum depth results in the proposed condition for each of the three design events.

It can be seen that the school site is flood free in all of the events and the peak water level results from this model may therefore be used to inform the required levels for re-grading the site.

Flood Level Differences

Figures 3.4–3.6 show the differences in maximum flood level and extent between the proposed school re-grading scenario and the baseline model. It can be seen that a substantial amount of floodwater has been displaced from the school site and that mitigation will be required.

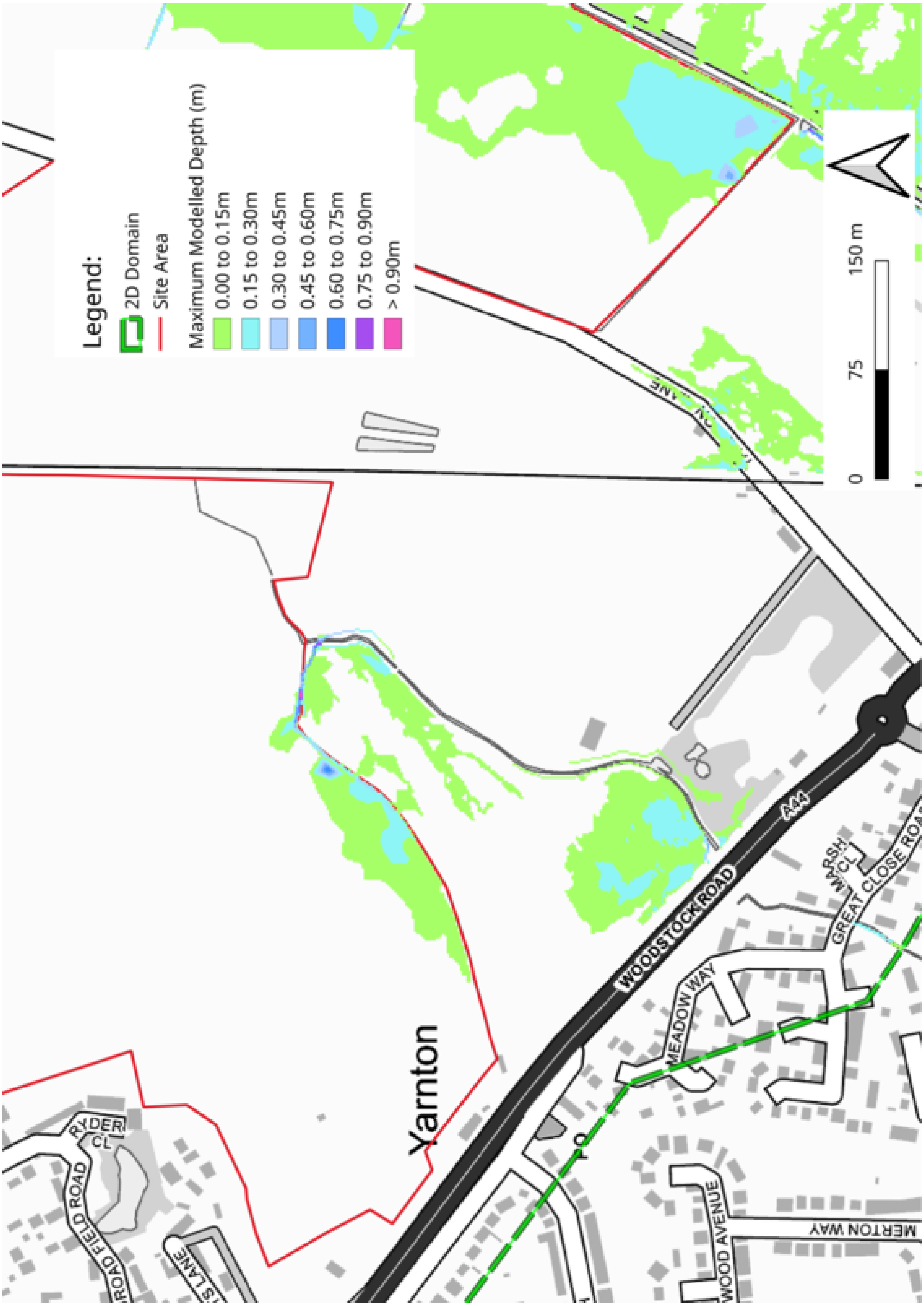

Figure 3.1: *Maximum modelled depths for the 1% AEP event with 26% climate change allowance.*

Figure 3.2: Maximum modelled depths for the 1% AEP event with 41% climate change allowance.

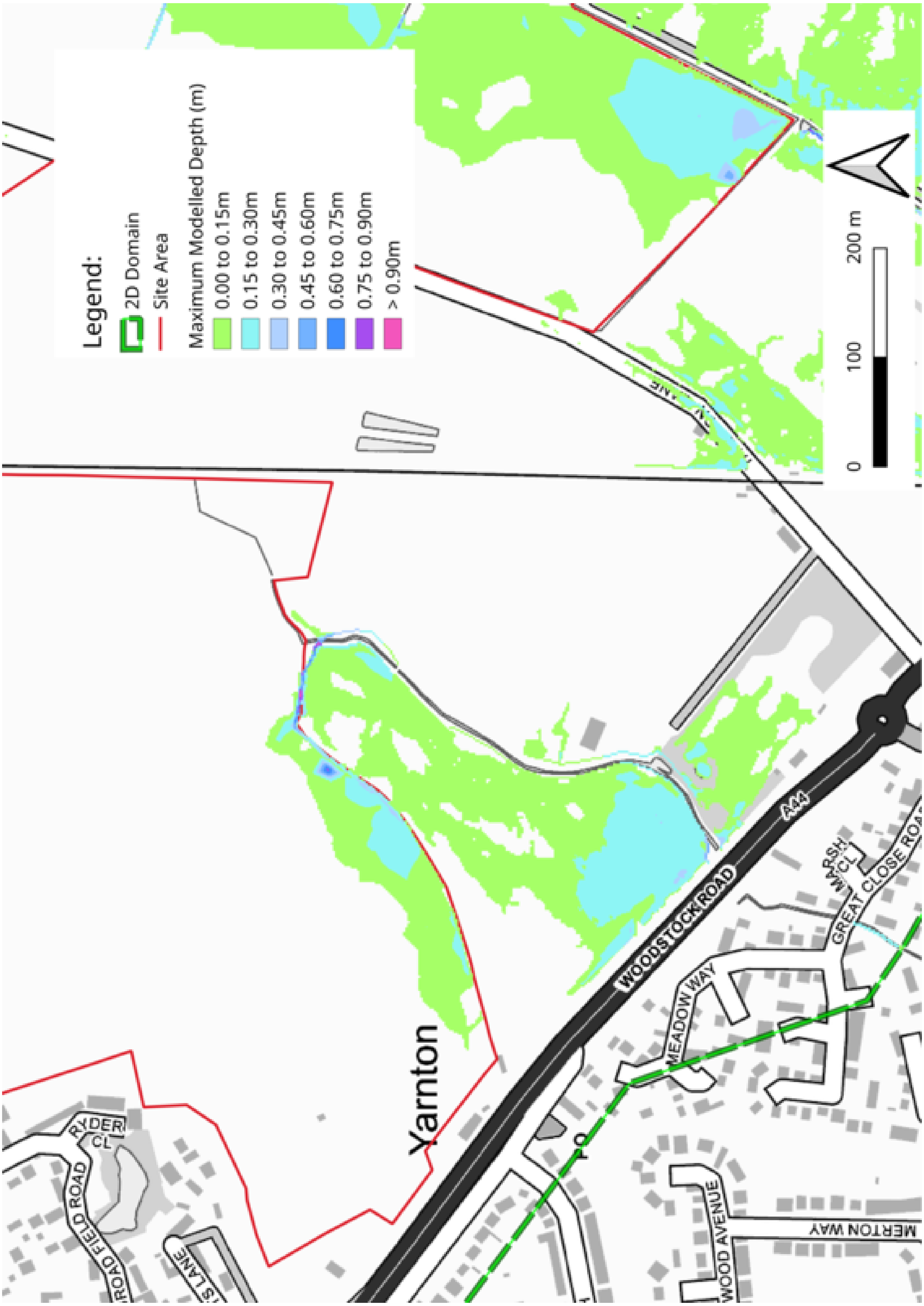

Figure 3.3: Maximum modelled depths for the 0.1% AEP present-day event.

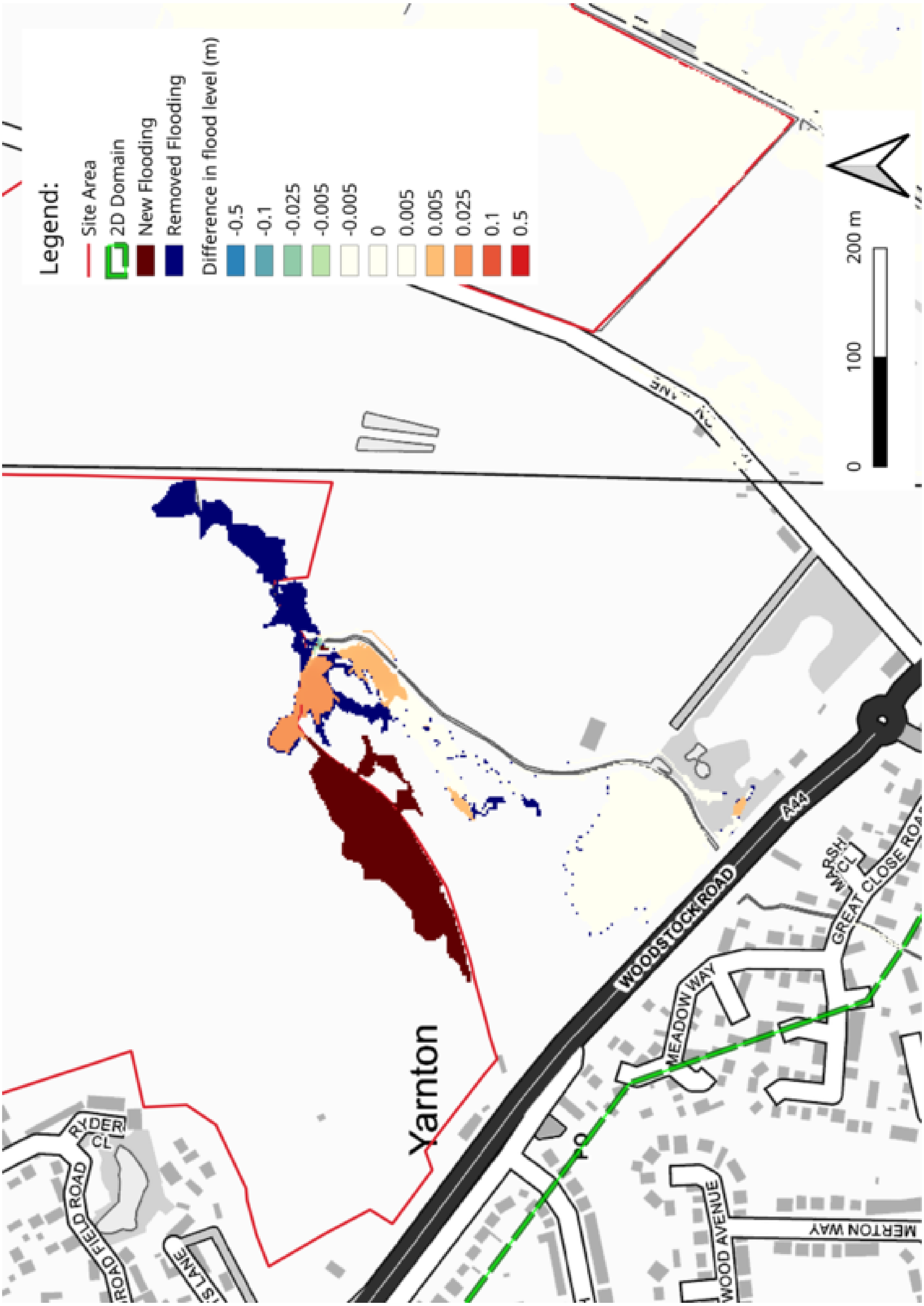

Figure 3.4: *Peak water level differences between the proposed and baseline conditions for the 1% AEP event with 26% climate change allowance.*

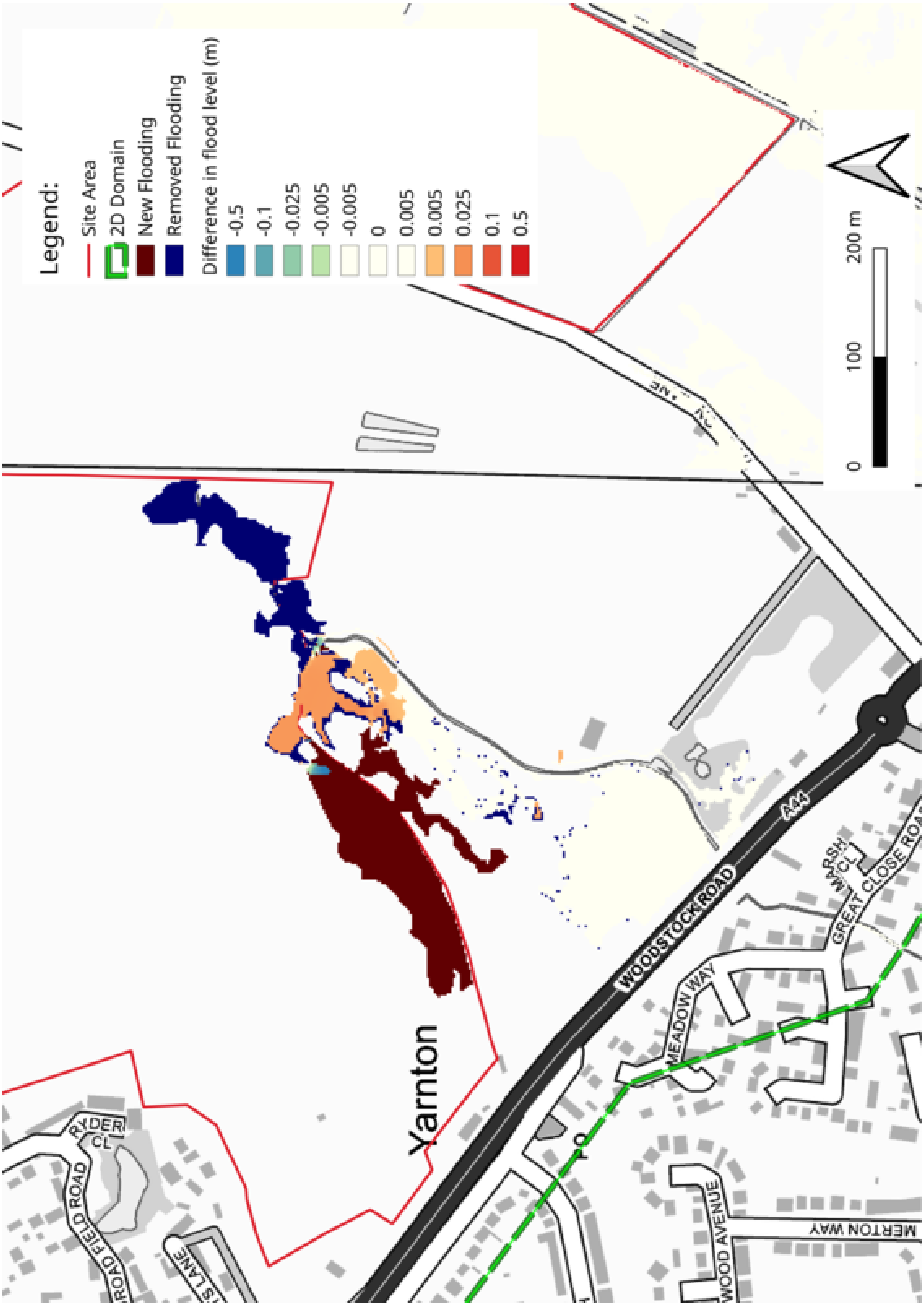

Figure 3.5: Peak water level differences between the proposed and baseline conditions for the 1% AEP event with 41% climate change allowance.

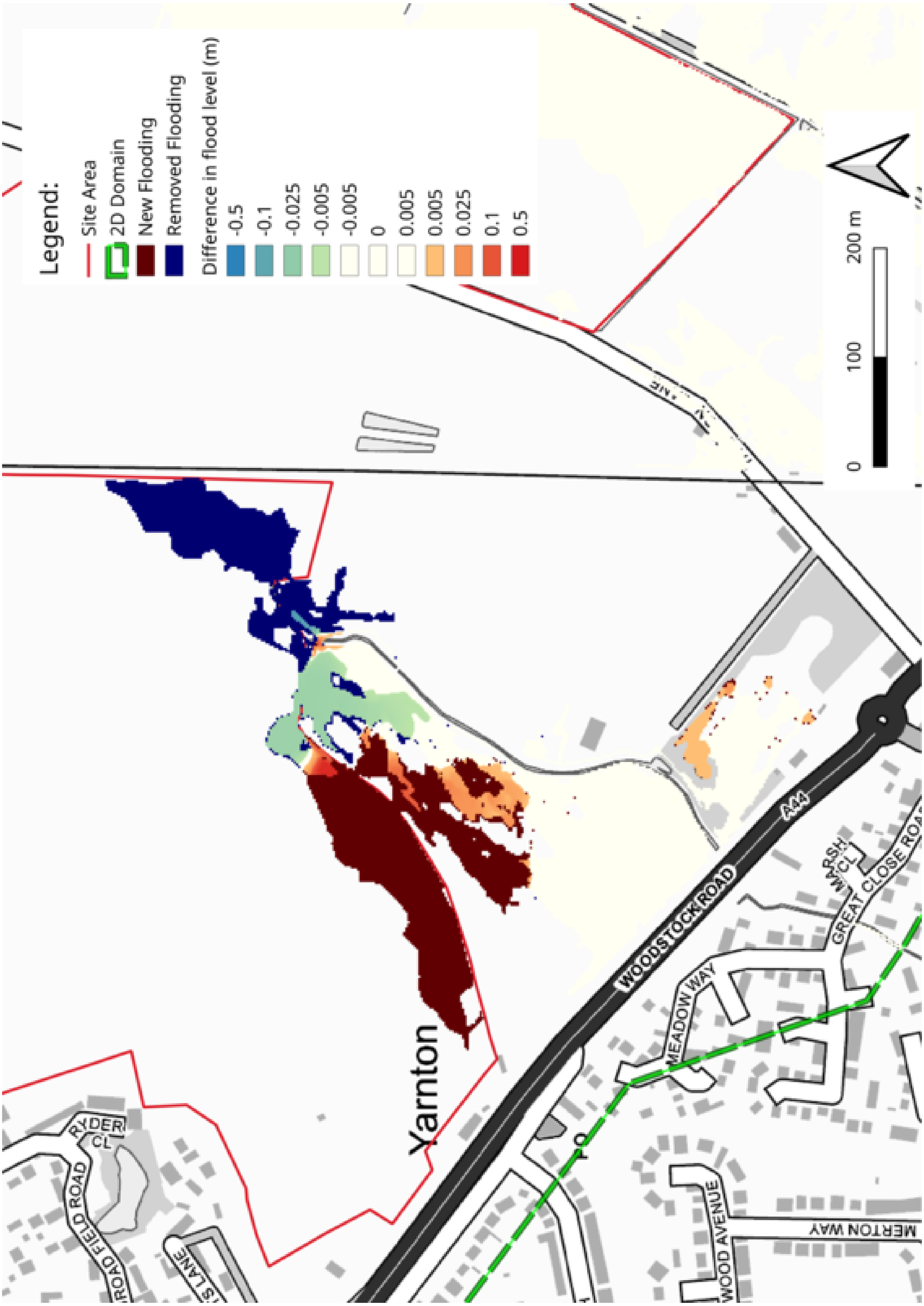

Figure 3.6: *Peak water level differences between the proposed and baseline conditions for the 0.1% AEP present-day event.*

4. Conclusions

Edenvale Young Associates have modelled the flood risk impacts of a proposed re-grading of the school site within the Begbroke Innovation District.

The proposed-condition modelling does not show any flood depths within the school site for any design event and the water levels from this model may therefore be used to inform the re-grading levels.

The models do show significant increases in flood risk to the west of the school site and mitigation for this will likely be required. It is felt that flood storage within the red line to the west of the school site would provide effective mitigation on a volume-for-volume basis.

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