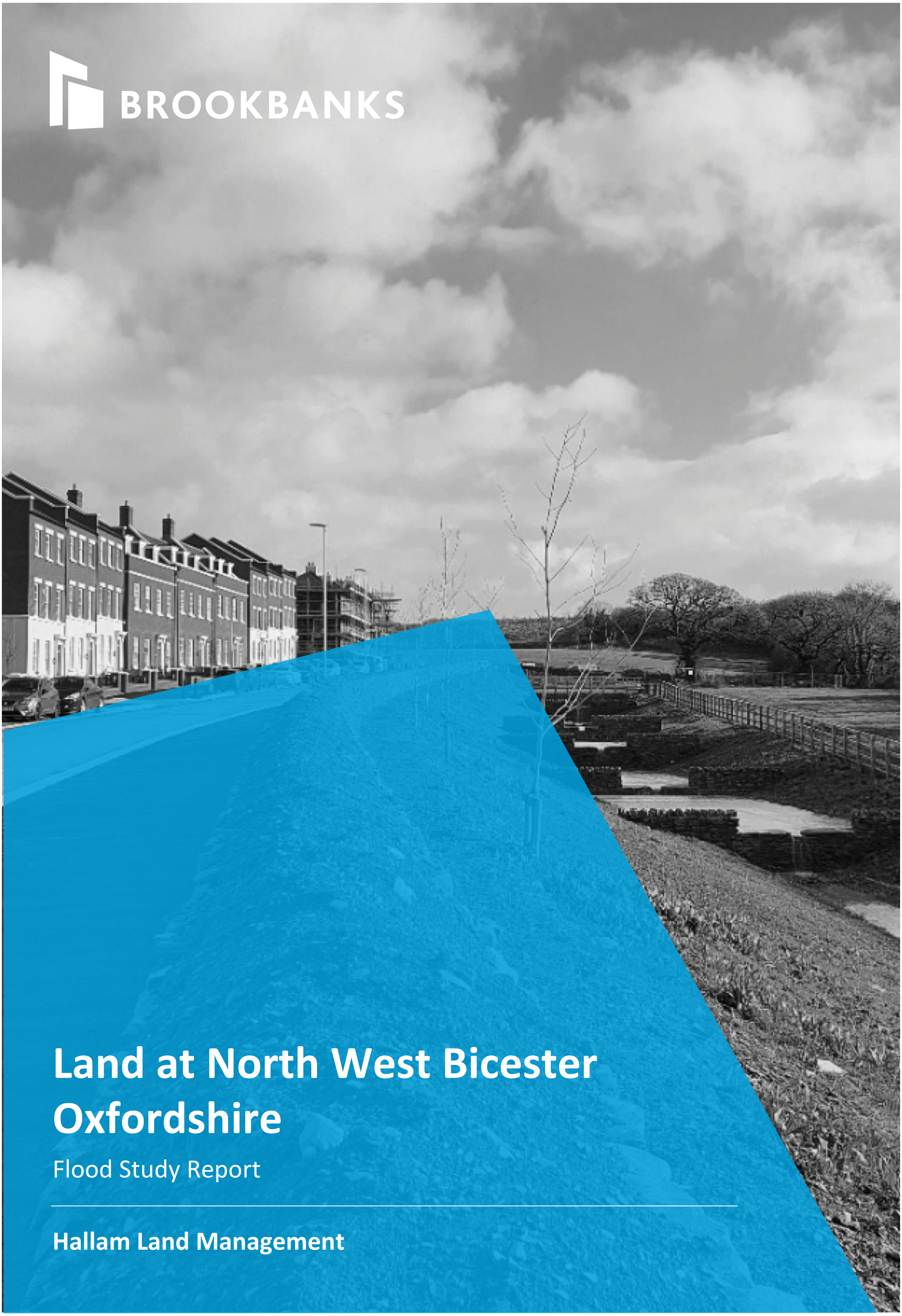
BROOKBANKS



Land at North West Bicester Oxfordshire

Flood Study Report

Hallam Land Management

Document Control Sheet

Document Title	Flood Study Report
Document Ref	10663 FS01 Rv0
Project Name	Land at North West Bicester
Project Number	10663
Client	Hallam Land Management Ltd

Document Status

Rev	Issue Status	Prepared / Date	Checked / Date	Approved / Date
0	DRAFT	K. Miller 29.06.2023 A. Marcotegui 29.06.2023	S. Mirams 03.07.23	R. Boyle

Issue Record

Name / Date & Revision	03.07.23					
Ben Meynell – Hallam Land Management Ltd	0					

Contents

Figures

Tables

Appendices

1 Introduction

1.1 Brookbanks is appointed by Hallam Land Management Ltd to complete a Flood Study Report (FS) for a proposed mixed use development at Land at North West Bicester.

1.2 An outline planning application (Ref 21/04275/OUT), including a Flood Risk Assessment and Surface Water drainage Strategy, was submitted to the Environment Agency. Comments on the application was received on the 20^{th} April 2022 and 9^{th} January 2023 which required that a detailed flood model to be developed. Following receipt of these comments Brookbanks requested a meeting with the EA to discuss but at the time of writing this meeting has not been arranged and, as such, this report provides reference to published national and local guidance in the absence of specific requests from the EA.

1.3 Therefore, the purpose of this FS report is to understand and provide detailed information on the current fluvial flood risk across the Site and to demonstrate that the development is acceptable once a mitigation strategy has been established.

1.4 This report will therefore, summarise the findings of the modelling and specifically address the following issues in the context of the current legislative regime:

- Existing Flooding Risk – Baseline,
- Proposed Development,
- Blockage Scenario,
- Sensitivity Analysis.

2 Study Area

Location and Details

2.1 The proposed development lies to the north-west of the Bicester in Oxfordshire. For the purpose of this site description the red line has been spilt into two areas. The eastern area is bound by Bucknell village to the north, agricultural fields to the east, by the A4095 and the Lords Lane roundabout to the south and Bicester Road/Bucknell Road to the west. The western area is bound by the railway line to the west, agricultural fields to the north, Bicester Road/ Bucknell Road to the east and Lords Lane roundabout to the south.

2.2 The site is currently undeveloped agricultural land and has not been historically subject to any significant built development.

Existing Drainage Network

2.3 The site is crossed by three ordinary watercourses. The first watercourse drains from the west crossing the railway line and flowing adjacent to Hawkwell Farm (named West for this report). The second watercourse flows along the northern boundary of the development site that drains Bucknell and Manor Farm (named North for this report) and the final watercourse flows south, crossing through Caversfield (named East for this report). The North watercourse joins the East watercourse at Caversfield, before continuing south until it joins the West watercourse just north of Lords Lane (A4095) crossing.

2.4 The Site location is shown indicatively on **Figure 2-1**.

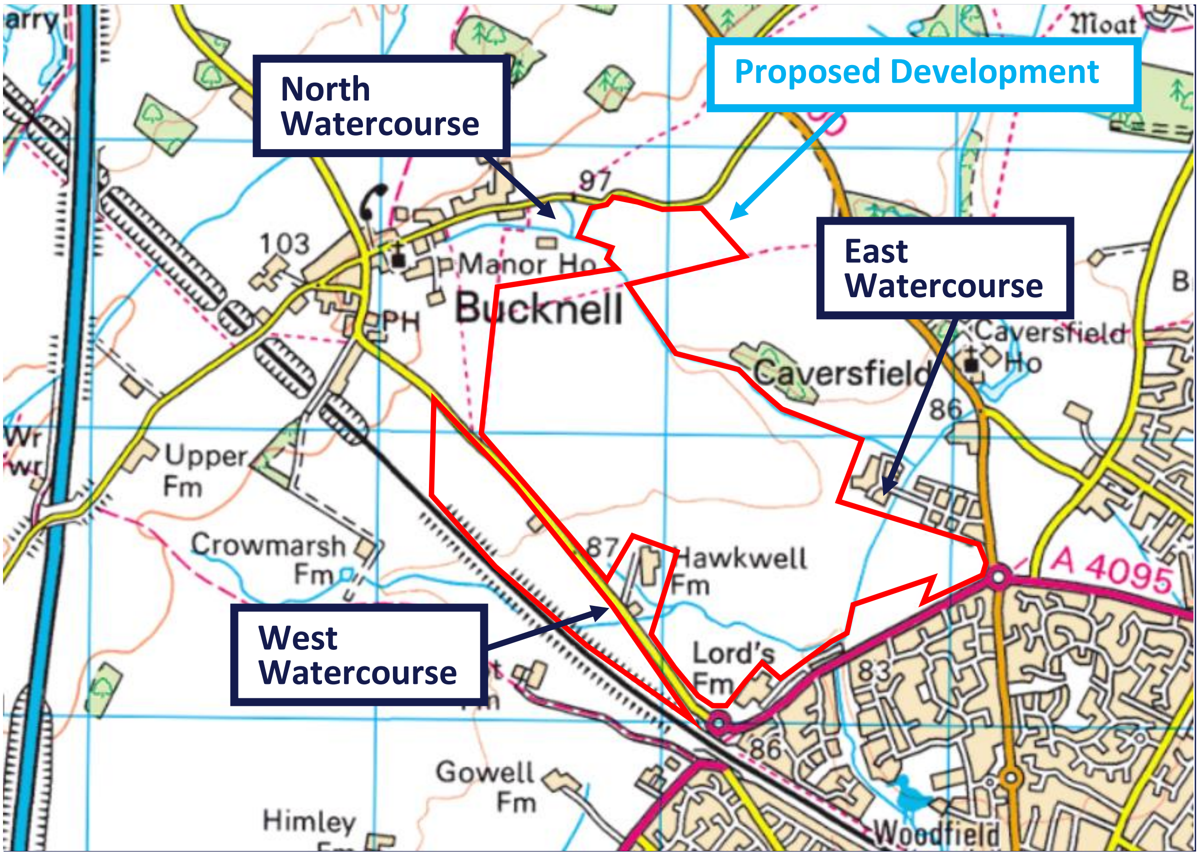


Figure 2-1: Site Location (Bing Maps, 2023)

Development Criteria

2.5 The following development is proposed at the site:

- Up to 3,100 new homes
- A mixed use local centre
- A school Site
- A school playing field extension to the existing Gagle Brook Primary School
- Extensive green area to the north comprising sports, recreation and play areas and a country park
- Allotments and community farm
- Burial ground
- 4 LEAPs, 2 NEAPs and a MUGA across the Site
- Employment/business use area
- Retention and enhancement of existing hedgerows
- Green corridor alongside the river
- Primary Street

Environment Agency (EA) Modelling

2.6 The EA was consulted at the start of the modelling process, in order to obtain the existing flood model (product 5, 6 & 7) for the area.

2.7 A model was produced for the Langford Brook (Bicester) & Pingle-Back-Pure in 2010. However, the model only begins to the south of the A4095, which forms the southern boundary of the development. The EA model extent is shown in **Figure 2-2**.

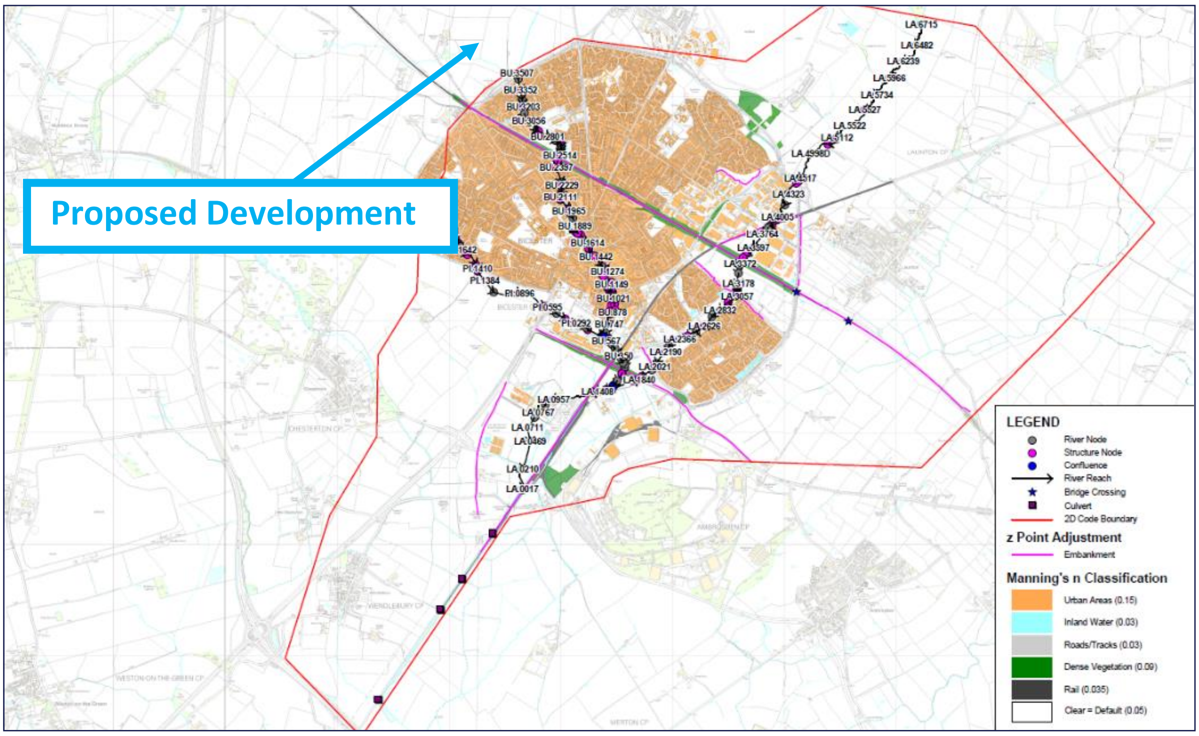


Figure 2-2: EA Langford Brook (Bicester) & Pingle-Back-Pure Model Extent. Source: Bicester Flood Risk Mapping Study

2.8 As there is no current model for the development Site, a model was required to be developed in order to determine the level of risk to the site and meet the requirements of the EA.

2.9 The model has been built to review the flood risk on all three watercourses across the Site starting at the edge of development with the downstream boundary meeting where the EA model begins, south of the A4095.

3 Technical Method and Implementation

Topographical Survey

3.1 A topographical survey of the Site was completed by MK Surveys in September and November 2014. An additional watercourse cross sectional survey was completed by MK Surveys in February 2023, which included both onsite watercourses. The watercourse survey area is illustrated on **Figure 3-1** and the cross section information has been included as **Appendix A**.

Figure 3-1: Watercourse Survey Extent

LiDAR Data

3.2 LiDAR was obtained from the EA open data source (DEFRA). The 1m resolution filtered LiDAR dataset (DTM) 2022 has been used to define the ground model used in the hydraulic model as a base for the 2D zone Z points.

3.3 The LiDAR was compared against the Site topographical survey to ensure that the modelling provides an accurate representation of the Site.

4 Hydrology

Methodology

4.1 Brookbanks has undertaken a detailed hydrology study for the study area, which focused on the storm events outlined below.

- 1 in 100-year (1% AEP)
- 1 in 100-year + 15% allowance for climate change (1% AEP + 15%CC) Central Estimate
- 1 in 100-year + 25% allowance for climate change (1% AEP + 25%CC) Higher Estimate
- 1 in 100-year + 49% allowance for climate change (1% AEP + 49%CC) Upper end Estimate
- 1 in 1000-year (0.1% AEP)

4.2 The climate change allowances that have been applied correspond to the those identified for the Cherwell and Ray Management Catchment peak river flow allowances. The catchment in which Bicester is located.

4.3 The methodology for the hydrological assessment was determined by the requirements of the work for LLFA/EA which required robust estimates of inflows for use in the modelling. The assessment included:

- A review of all available data allowing for detailed response for catchment response,
- The update of flood peak data to provide updated flood estimates,
- An assessment of the critical storm duration for the catchment.

Watercourse and Catchment Characteristics

4.4 The ordinary watercourses that cross the Site are located within the FEH Catchment 457650, 224000 and drains a total area of 10.53km^2 (1053ha).

4.5 In order to calculate the flow within each channel a further three smaller catchments where obtained. le

4.6 All three catchments drain in south easterly direction towards the A4095 with the highest point at circa 115m AOD and a low point at circa 79mAOD along the A4095.

4.7 The hydrology of the FEH catchment has been analysed at 3 Flood Estimation Points (FEPs) using the Flood Estimation Handbook (FEH) statistical analysis and Revitalised Flood Hydrograph (ReFH). Each of the identified watercourses hydrological calculations were required to derive peak flow estimates and design hydrographs for input into the hydraulic model.

4.8 The FEH catchments are illustrated on **Figure 4-1**.

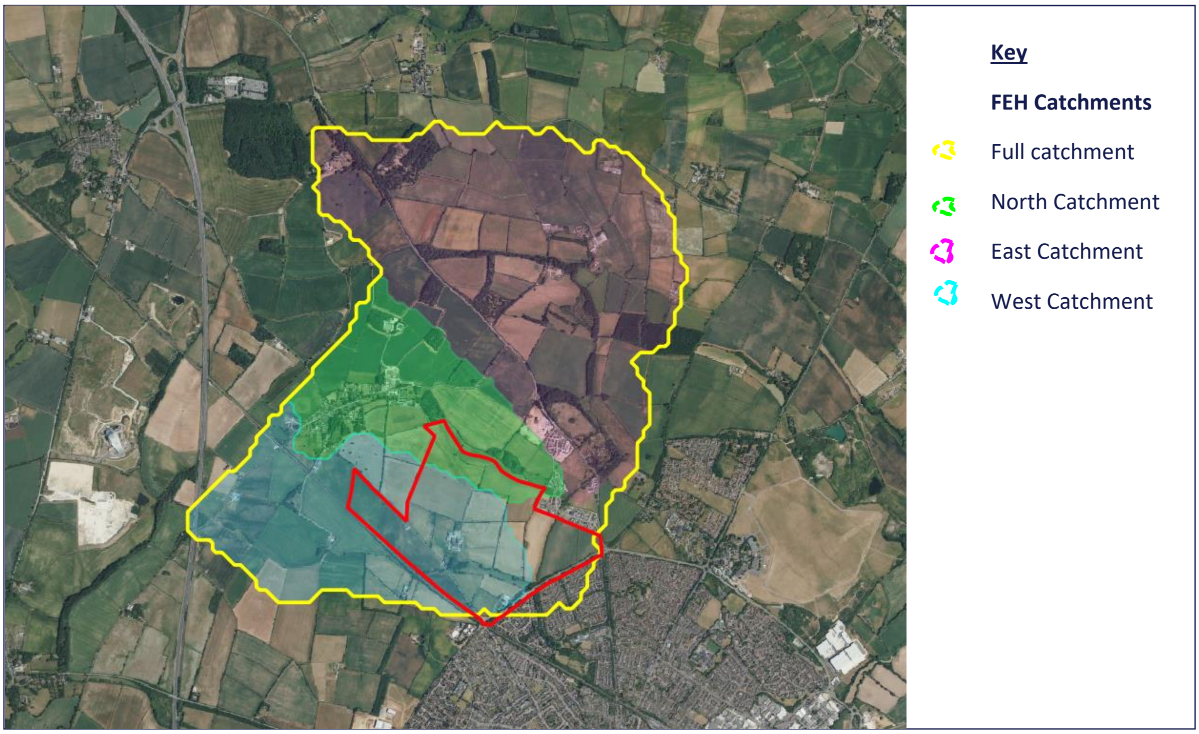


Figure 4-1: FEH Catchment Areas

4.9 Important catchment descriptors at each subject site are presented in **Table 4-1**.

Site Code	AREA	FARL	PROPWET	BFIHOST19	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT
East	5.26	0.949	0.32	0.770	2.64	17.5	654	17.09	0.0062
West	2.79	1.0	0.32	0.845	1.72	14.2	639	6.65	0.0040
North	1.89	1.0	0.32	0.799	1.63	18.4	647	13.92	0.0251

* Note: No changes have been made to the catchment descriptors

Table 4-1: Catchment Descriptors at Each FEP

4.10 All FEH catchments were compared against available information with respect to 'key' descriptors that influence calculated flows. These included AREA, SPRHOST and URBEXT amongst others. For these checks have been undertaken against the FEH data and topographical information to confirm the areas are correct, soil plans to ensure the classification of the site (i.e. permeable, non-permeable etc) is considered as being correct and aligned, and $\text{URBAN}_{\text{50k mapping}}$ to ensure the URBEXT values remain correct and reflect any updated/new development within the study catchments.

4.11 The National River Flow Archive Peak Flow (NRFA) v11-1 has been used for the statistical analysis.

4.12 The latest FEH peak flow estimates reflecting the most up to date rainfall event data have been used when inputting the hydrology information. The peak flow from all FEP's are shown in the **Table 4-2**.

Site Code	Flood peak (m3/s) for the following return periods (in years)				
	100	100+15%CC	100+25%CC	100+49%CC	1000
East	1.868	2.148	2.335	2.783	3.441
West	0.671	0.772	0.839	1.000	1.237
North	0.991	1.139	1.238	1.476	1.825

Table 4-2: BCL Modelled Inflow at each FEP

4.13 The final choice of method is to use peak flows derived from the FEH Statistical method as this makes most use of the observed flow data within the catchment and is consistent with guidance.

4.14 To obtain hydrographs and the design storm needed to run the hydraulic Flood Modelled model, the ReFH2 rainfall runoff analysis was used and scaled to fit the FEH Statistical peak flows as outlined in **Table 4-2**.

4.15 The ReFH2 hydrograph for the and example catchment is shown in **Figure 4-2**.(note this is a theoretical assessment for the combined catchment and therefore does not reflect values in Table 4-2).

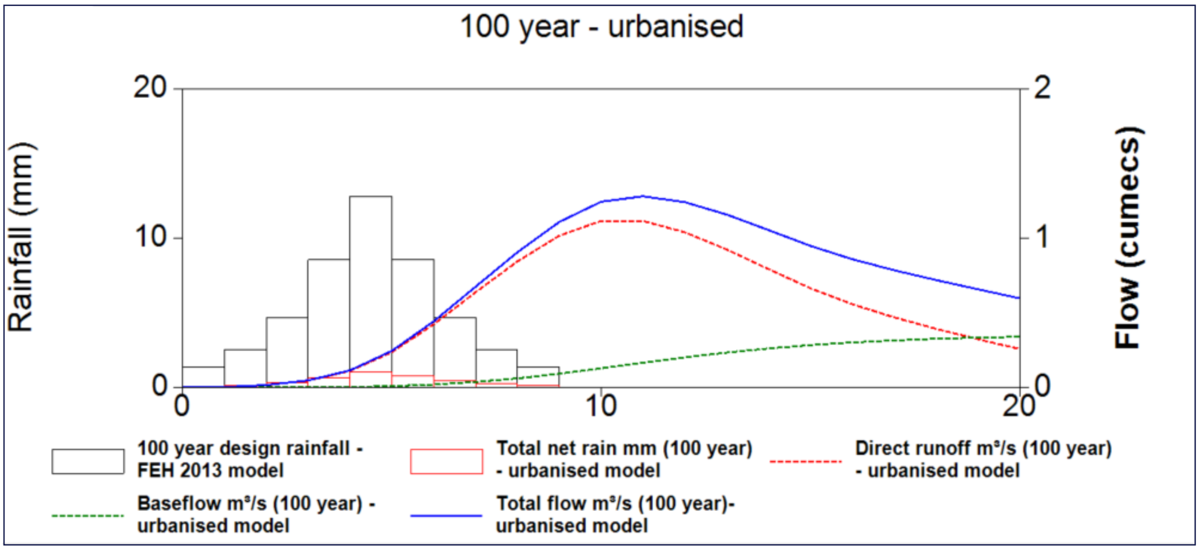


Figure 4-2: ReFH2 urbanised 1 in 100yr hydrograph, DS catchment

4.16 The method of scaling statistical peak flows to fit ReFH2 hydrograph is in line with good modelling practice and guidance.

4.17 An allowance of climate change has been applied to the peak inflows in line with current guidelines provided by EA. The development site lies within the Cherwell and Ray Management Catchment area therefore, the EA required that a 15% allowance (central estimate), 25% allowance (higher estimate) and 49% allowance (Upper estimate) be tested.

4.18 The full FEH calculation Record it is included in **Appendix B**.

5 Hydraulic Modelling

1D Domain

5.1 This section provides an overview of how the model of the watercourse network was constructed, after receiving and reviewing the EA's model.

5.2 In February 2023 a watercourse cross section topographic survey was undertaken by MK Surveys. All three watercourses on site where surveyed. The first watercourse drains from the west crossing the railway line and flowing adjacent to Hawkwell Farm (named West for this report). The second watercourse flows along the northern boundary of the development site that drains Bucknell and Manor Farm (named North for this report) and the final watercourse flows south, crossing through Caversfield (named East for this report). The North watercourse joins the East watercourse at Caversfield, before continuing south until it joins the West watercourse just north of Lords Lane (A4095) crossing.

5.3 From both the information received from the topographic survey and a Site walkover it was found that the northern watercourse is known to be dry for long periods of time. Therefore, this section of watercourse has been built with using ESTRY (1d). The 1d_nwke ESTRY feature has been linked to the upstream section of the Flood Modeller East watercourse with X1DH connection and Head-Time to the upstream cross section.

5.4 In order to run a stable model within Flood Modeller Pro 6.0, the East and West watercourses were run with the minimum baseflow.

5.5 For this model three upstream boundary's have been used, one at the start of each stretch of watercourse.

5.6 The boundary conditions (bc_dbase.csv) have been located at; East of Manor Farm for the North watercourse, between the railway line and Bucknell Road for the West watercourse and at Caversfield for the East watercourse. Where flows were input in Flood Modeller these were done so via ReFH boundaries.

5.7 Initial water levels of the North watercourse were set at 0 with 1d_IWL. The base flow conditions for the West watercourse was set to 0.04m^3/s (40l/s) and for the East 0.06m^3/s (60l/s).

5.8 Peak flows were taken with statistical analysis and shaped with ReFH2 to create the bc_dbase and the hydrographs units at the Flood Modeller section.l

5.9 Bank levels have been calculated from the topographic survey cross sections and 2d_zpt points extracted connected vie 2d_zpt lines representing both banks.t

5.10 The structures and channel cross sections are shown in **Appendix A**. Structures within the model are also detailed from section 5.15.

5.11 The downstream boundary was set at a gradient of 0.0015 (1 in 666) located 50m downstream Lords Lane (A4095) based on levels taken from the topographical survey. The sensitivity analysis of downstream boundary condition are at the Section 8 of this report.

5.12 The impact on the downstream boundary condition and possible variations has been determined in the sensitivity analysis in Section 8. For reference the downstream limit of the model was located at the upstream limit of the existing EA model and immediately downstream of a significant hydraulic control. As such it was deemed appropriate.

5.13 The hydraulic model extent is illustrated on **Figure 5-1**.

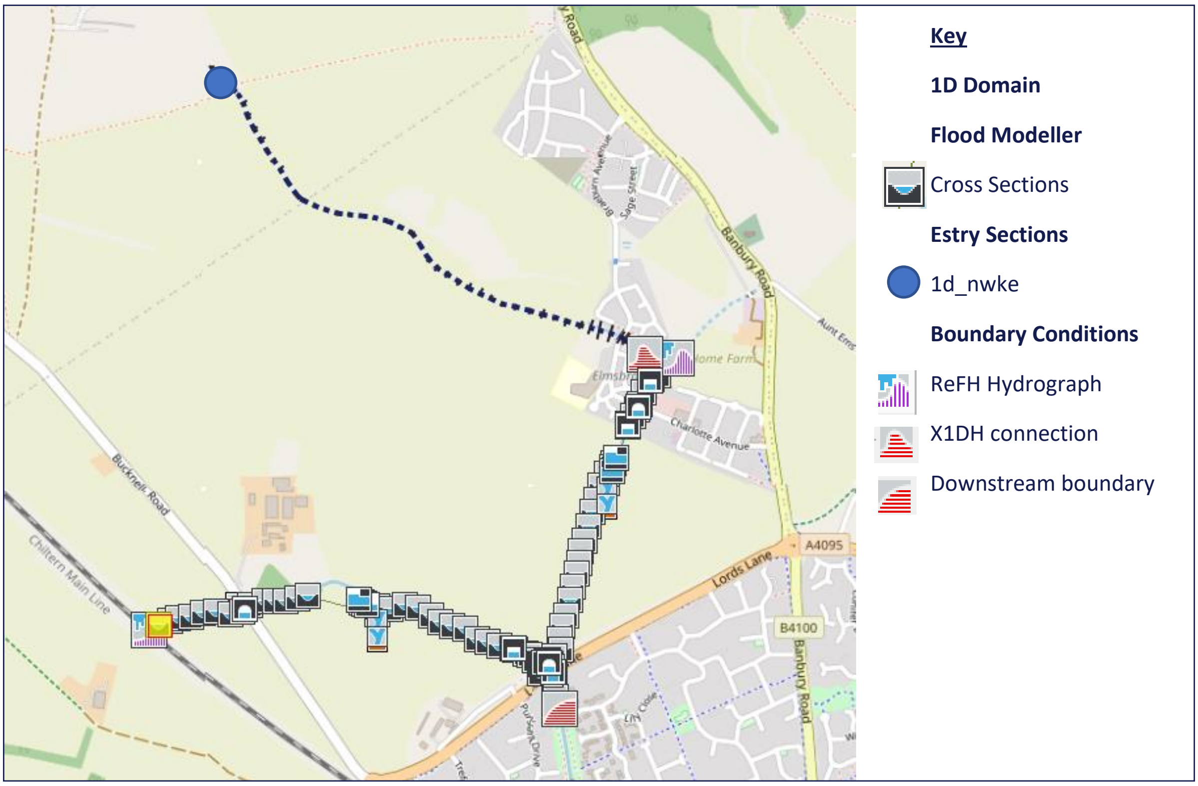


Figure 5-1: 1D Hydraulic Model Extent

5.14 There are 5 hydraulic structures within the Estry (North watercourse) and 8 in the Flood Modeller section (West and East watercourses) all of which are included within the model.

5.15 The Structure Log file for the baseline and development scenario is included within the **Appendix C of** this report.

Figure 5-2: Structures along the East Watercourse

5.16 The East Watercourse includes one arch bridge at Caversfield and also an arch bridge at the downstream section, shown at **Figure 5-2**. These were included within Flood Modeller using the USBPR bridge functions owing to their dimensions and flow widths. This is in line with model guidance.

5.17 The West watercourse has some culverts at Hawkwell Farm access and a small arch bridge at Bucknell Road crossing, shown in **Figure 5-3**.

Figure 5-3: Hydraulic structures at West watercourse

5.18 The hydraulic roughness value for the watercourse was set as 0.035, according with Manning's n value for Channels (Chow, 1959). This value is suitable for main channels with some stones and weeds.

5.19 All the Flood modeller hydraulic structures have been modelled with spill units representing the deck of the bridge or footpath, such unit is set to zero to link with 2d domain model and avoid double counting flows.

5.20 The roughness variations has been modelled in the sensitivity analysis in Section 8.

5.21 The 1d domain has been linked with 2d domain TuFLOW in order to provide reliable results.

2D Domain

5.22 The 1m composite (2020) Digital Terrain Model (DTM) resolution LiDAR has been used to define the ground model within the 2D domains. A cell size of 2m has been used in order to achieve enough accuracy in the flood plain representation.

5.23 Bank-top elevations (taken from the topographic survey) have been applied to control the level at which water will start to overtop the banks and begin to flow out of the 1D channel into the 2D domain.

5.24 The spill from the 1D channel into the floodplain over the left and right banks is defined by (Head External) HX lines. The HX lines are defined along the banks of the channel.

5.25 Bed, bank and flood plain materials have been represented in the hydraulic model using Manning's roughness values. The Manning's roughness values are based on site visit, topographical survey data, photographic evidence and OS map.

5.26 The Manning's roughness coefficient was set at 0.054 for the floodplain. Within the 2D model, buildings are set with an elevated roughness value to slow the movement of water. Roads, tracks, and pavements were set with lower roughness value to reflect the smoother surfaces that would act as preferential flow routes during an event. Ven Te Chow (Chow, 1959) Manning's n for channels has been used to select roughness parameters.

5.27 The Manning's values used for each land-use classification is highlighted in **Table 5-1.**

Manning's r values	Description
Floodplain roughness (high grass)	0.054
General surface, unclassified	0.048
Buildings	0.500
Bushes and Trees	0.120
Gardens	0.036
Tracks and paths	0.048
Water	0.030
Roads	0.018

Table 5-1: Manning's Roughness Values

5.28 The model domain origin 2d_loc file is located at 80 degrees crossing Bicester Town, mostly perpendicular to the West and North flow direction.

Figure 5-4: 2D Active Area

5.29 The downstream boundary has been applied using the normal depth in 1d and 2d domains - Head Discharge-Q (HQ), the downstream slope has been calculated and set as 0.0015 (1in666).

5.30 The downstream boundary was set at a gradient of 0.0015 (1 in 666) located 50m downstream Lords Lane (A4095). The sensitivity analysis of downstream boundary condition are at the Section 8 of this report.

Baseline Model

5.31 A baseline model was built to establish the “As Existing” scenario, the benchmark for the proposed development scheme.

5.32 As stated above, the baseline model was newly constructed with a recent topographic survey and the most up to date LiDAR data to build the Digital Terrain Model (DTM). New FEH hydrology for all the sub-catchments was calculated.

5.33 The modelled events are as follows:

- 1 in 100-year (1% AEP)
- 1 in 100-year + 15% allowance for climate change (1% AEP + 15%CC) Central Estimate
- 1 in 100-year + 25% allowance for climate change (1% AEP + 25%CC) Higher Estimate
- 1 in 100-year + 49% allowance for climate change (1% AEP + 49%CC) Upper end Estimate
- 1 in 1000-year (0.1% AEP)

5.34 The baseline model was built as per the description, some of the assumptions and notes to take into consideration are as follows:

- The roughness coefficient values were selected to represent the reality at the 1D and 2D domain,
- The inflows added to the 1d domain (Estry) were hydrographs calculated with ReFH fitted to the statistical values, the hydrographs at the Flood Modeller are ReFH fitted to statistical values.
- LiDAR is 1m resolution. However, the 2d domain grid cell size was selected to be 2m resolution,
- The initial water level of the watercourses used are those measured the day of the topographic survey.
- The North watercourse is linked to the FMP 1d domain with X1DH connection.

5.35 The baseline model is illustrated on **Figure 5-5**.

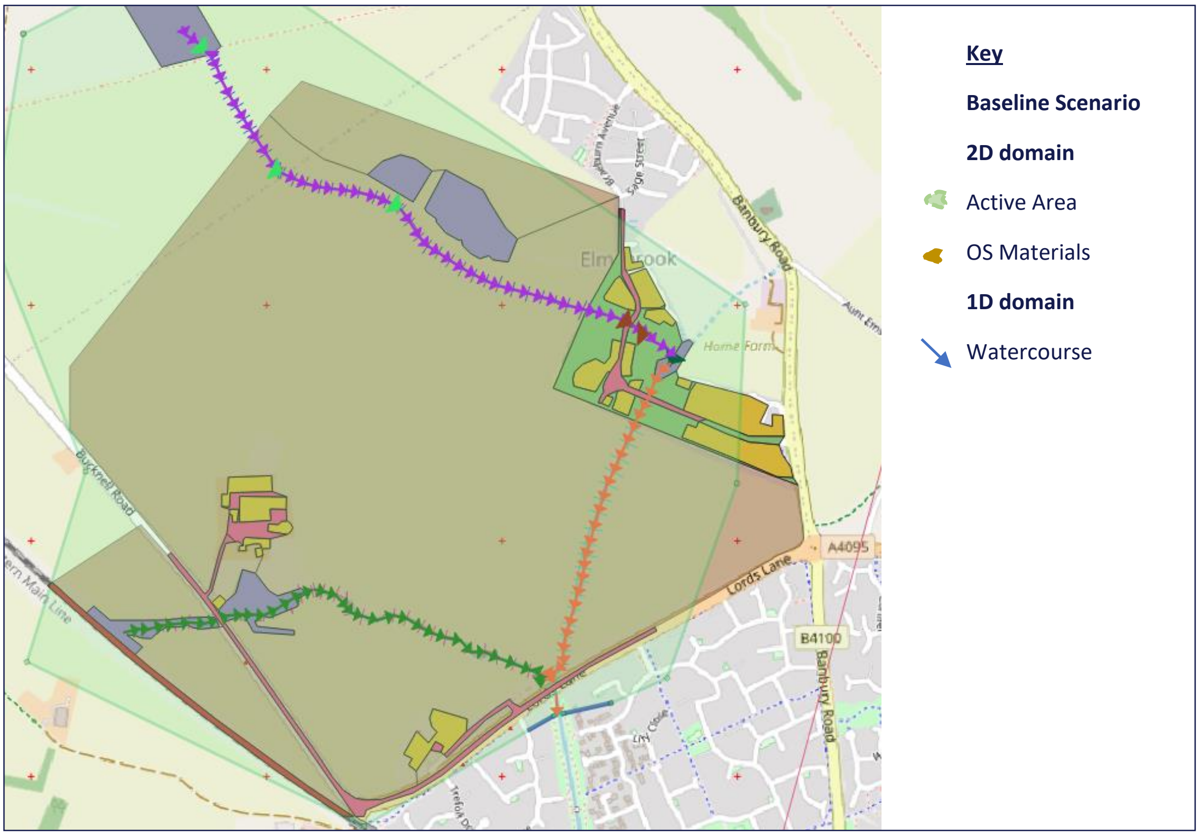


Figure 5-5: Baseline Scenario

Proposed Development

5.36 The new development includes two new access road culverts, the replacement of the Hawkwell Farm access culverts and one cycle/footpath bridge.

5.37 The proposed culverts comply with the CIRIA (C786) freeboard allowance, illustrated in **Figure 5-6**.

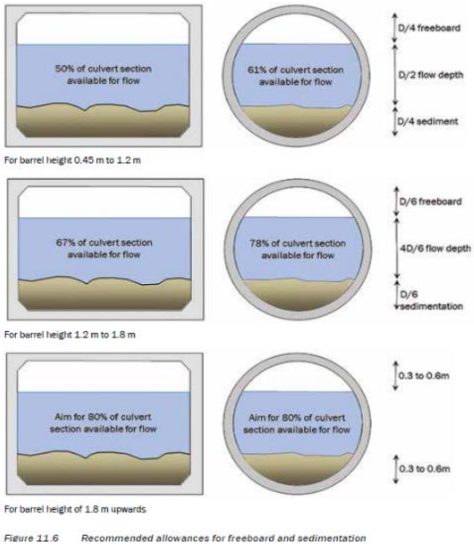


Figure 5-6: Culvert, screen and outfall manual. CIRIA (C786)

5.38 The size of bridges and therefore the culverts have yet to be determined, so the model has provided the smallest culvert possible that allows flow through without surcharge.

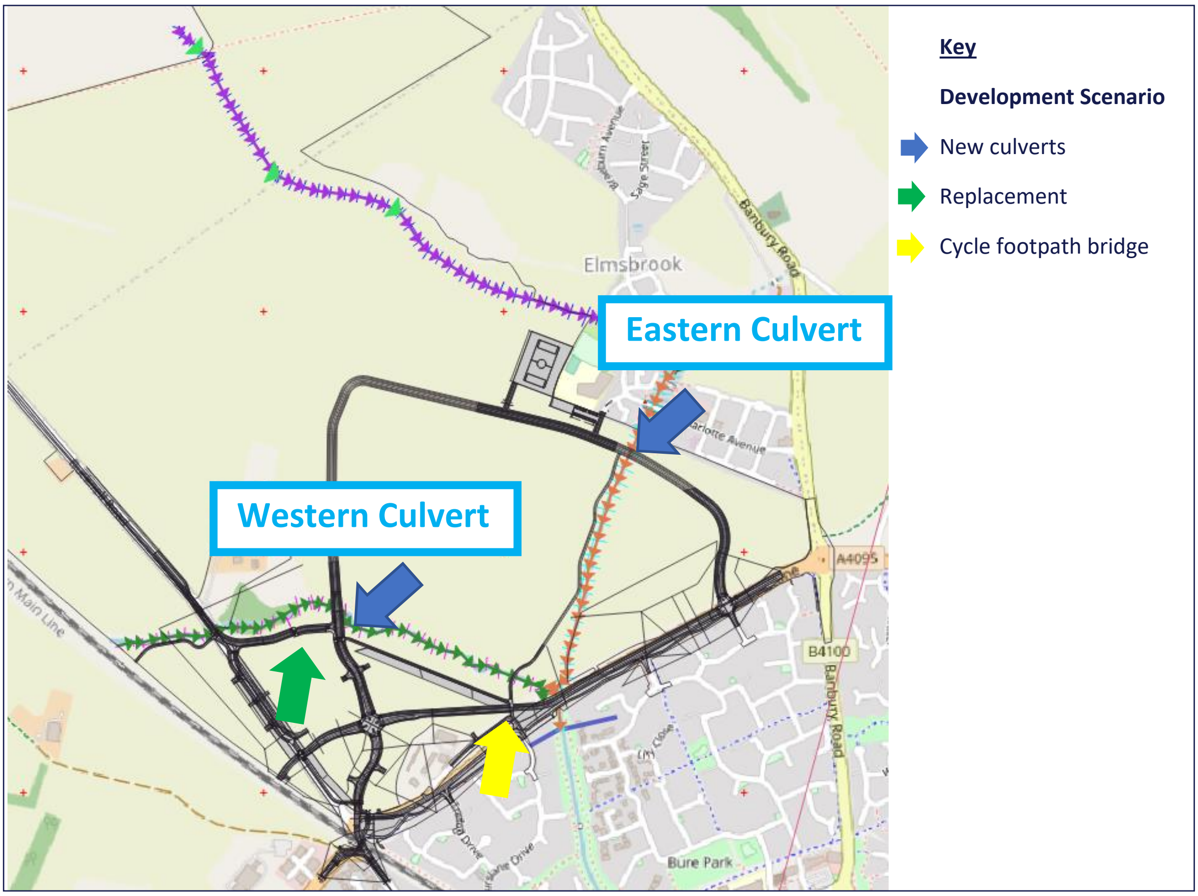


Figure 5-7: Development Scenario

5.39 The new structures have been modelled over the FMP baseline section, adding the structures with inlet and outlet losses and spill units at the deck levels, the spill units have been deactivated for the linked model in 2d domain.

5.40 The proposed culvert dimensions are as follows:

- East 4.0m wide X 1.2m height
- West 1.5m wide X 1.0m height

5.41 The proposed development includes a buffer green zone along the watercourses without any development.

5.42 The Structure log file includes the new structures added to the development and the structure replaced within the **Appendix C** of this report.

6 Baseline Model Results

6.1 The Baseline model shows the results "As Existing", illustrating the current flood risk across the Land at North West Bicester area.

6.2 The baseline results shows that:

- Water overtops the watercourse right bank at the North watercourse, flowing parallel to the watercourse, this is due to the existence of 3 culverts upstream which act as a restriction to in channel flows due to a lack of capacity for all modelled events. This occurs with events of 1% AEP (1 in 100yr) and above.
- At the junction between the West and East watercourses, flows exceed channel capacity and result in ponding in an existing lower elevated section of the site. This happens for all modelled events.
- For events up to the 1 in 100yr (1%AEP) with climate change, flood waters overtop the Hawkwell Farm access flowing downstream parallel to the watercourse. Approximately 90m downstream the water rejoins to the watercourse.

6.3 The baseline maximum flood depth is illustrated on **Figure 6-1**.

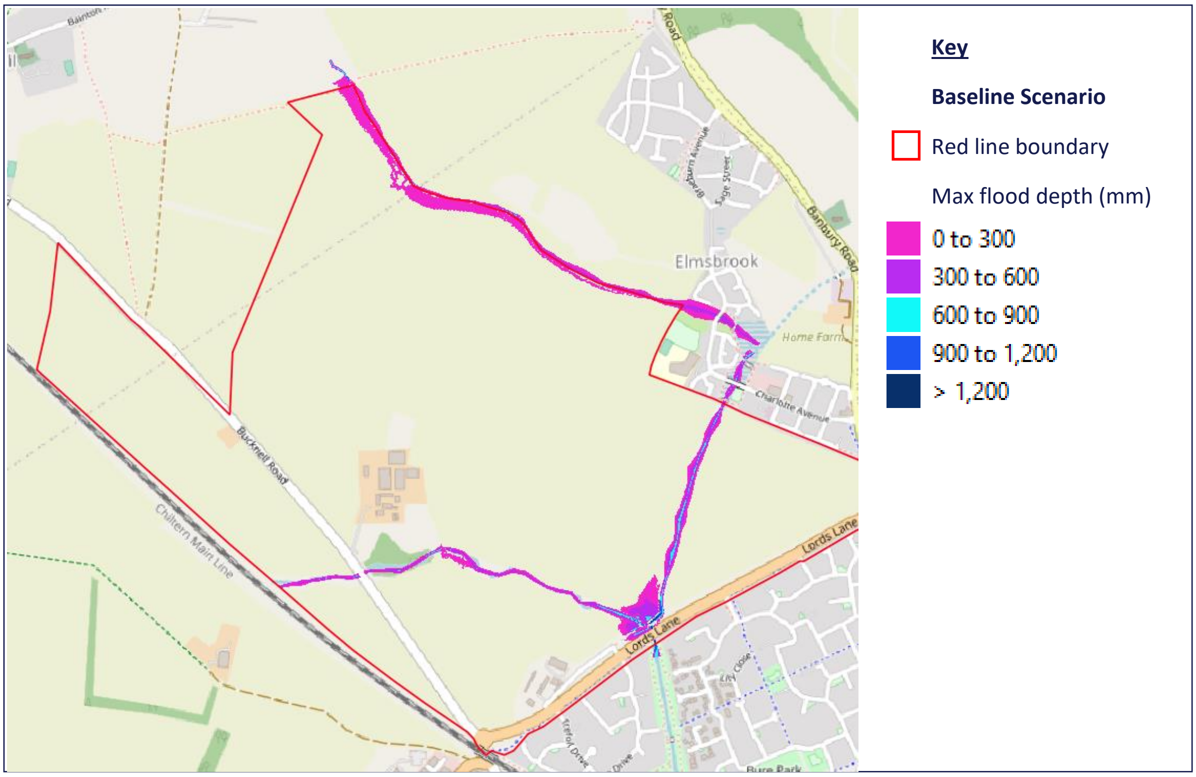


Figure 6-1: Baseline scenario, maximum flood depth 1 in 100yr +25%CC (higher estimate)

6.4 For the 1 in 1000yr baseline scenario, the maximum flood height reaches 79.754mAOD at the downstream section near the Lords Lane crossing.

6.5 Detailed flood map depth for all the events in the Baseline model are located in **Appendix D**.

7 Development Model Results

7.1 This section outlines the development scenario with the replacement of 1 structure and the addition of 3 new culverts, as described in section 5.

7.2 The proposed development includes a minimum 8m green buffer zone along the watercourse without any development, keeping the existing floodplain.

7.3 The results from the development scenario show that at the North watercourse overtops its right bank, with flood water flowing parallel to the watercourse, as shown in the baseline scenario, as no changes have been made to this watercourse. As flooding remains within the green corridor there is no risk of flooding to the proposed SuDS basins or residential development.

7.4 The replacement of the Hawkwell Farm access culvert improves the conveyance of flood waters and therefore, reduces the overall risk of flooding, with no risk of surcharging.

7.5 Similar to the baseline scenario for the 1%AEP (1 in 100yr) event the junction between the West and East watercourses, flood water overtops the banks flooding the relative low lying areas.

7.6 The proposed cycle and footpath bridge has been located outside the maximum flood extent in the downstream area to avoid being at risk of flooding or creating any displacement of flooding.

7.7 The development scenario maximum flood depth is illustrated on **Figure 7-1**.

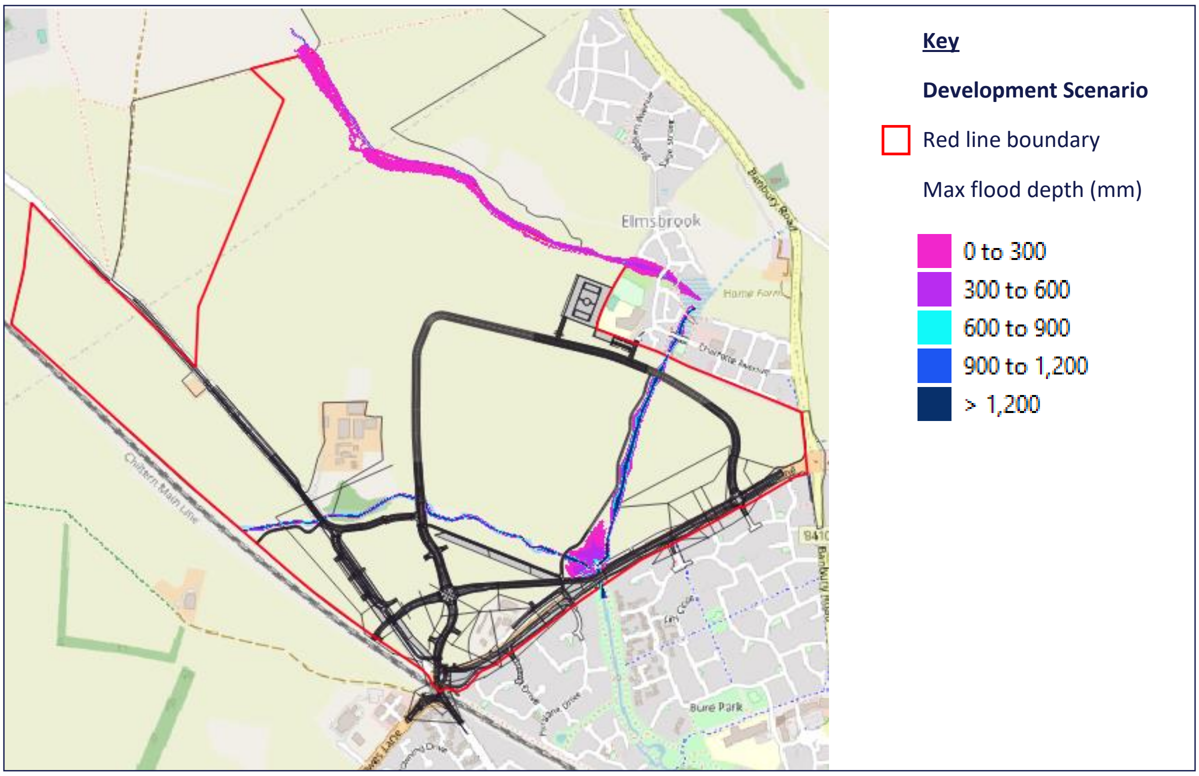


Figure 7-1: Development scenario, maximum flood depth 1 in 100yr +25%CC (higher estimate)

7.8 As shows in **Figure 7-1** above, the proposed development scenario does not identify any additional flood extent or increase the flood risk downstream.

7.9 The new culvert located across the East watercourse again conveys the flow more efficiently and is not affected by flooding waters.

7.10 The proposed culvert at the East watercourse cross section at maximum depth for 1 in 100yr+25%CC is illustrated on **Figure 7-2**.

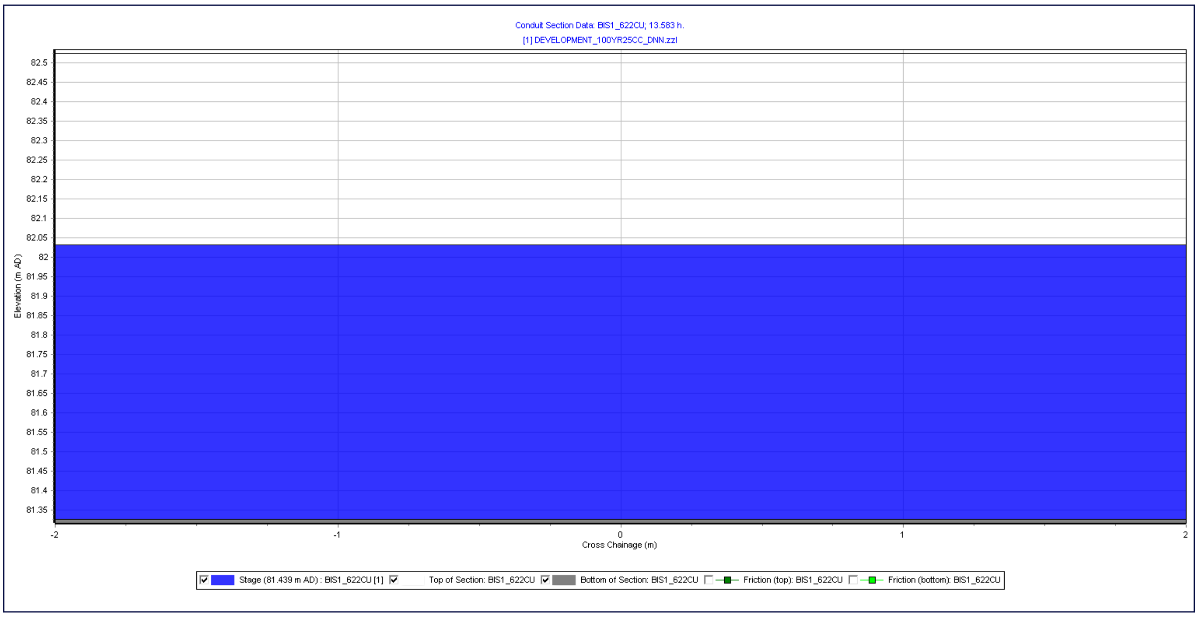


Figure 7-2: Proposed culvert, East watercourse- maximum flood depth for 1 in 100yr +25%CC

7.11 The proposed culvert at the West watercourse cross section at maximum depth for 1 in 100yr+25%CC is illustrated on **Figure 7-3**.

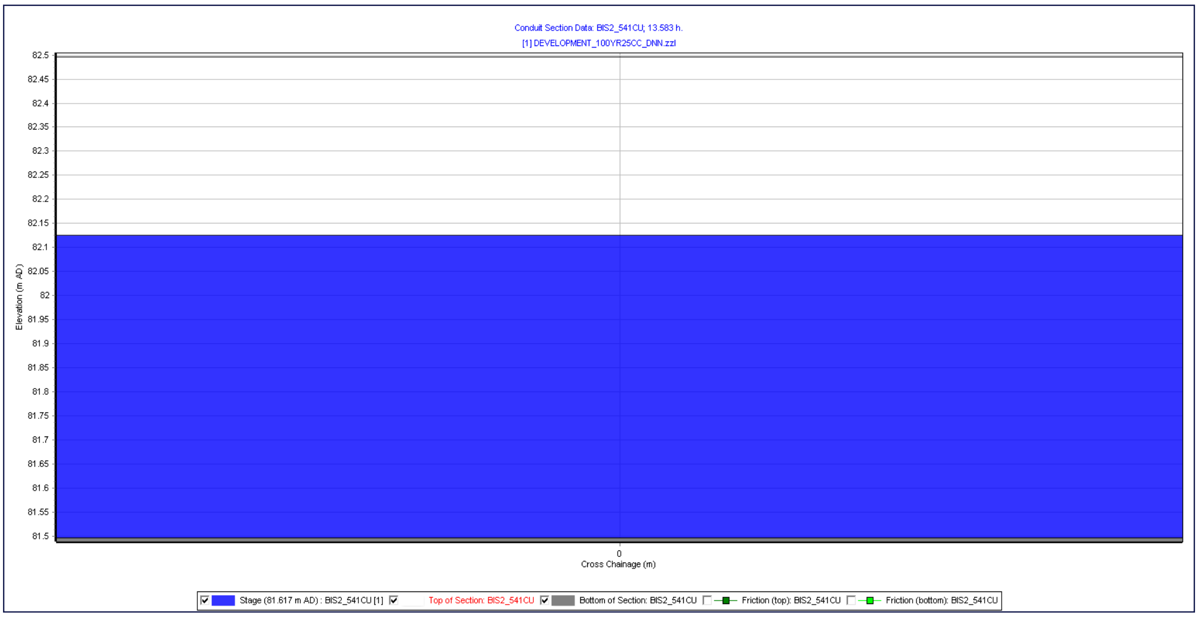


Figure 7-3: Proposed culvert, West watercourse- maximum flood depth for 1 in 100yr +25%CC

7.12 The downstream Stage versus Time for 1 in 100yr +25%CC event is shown in **Figure 7-4** below.

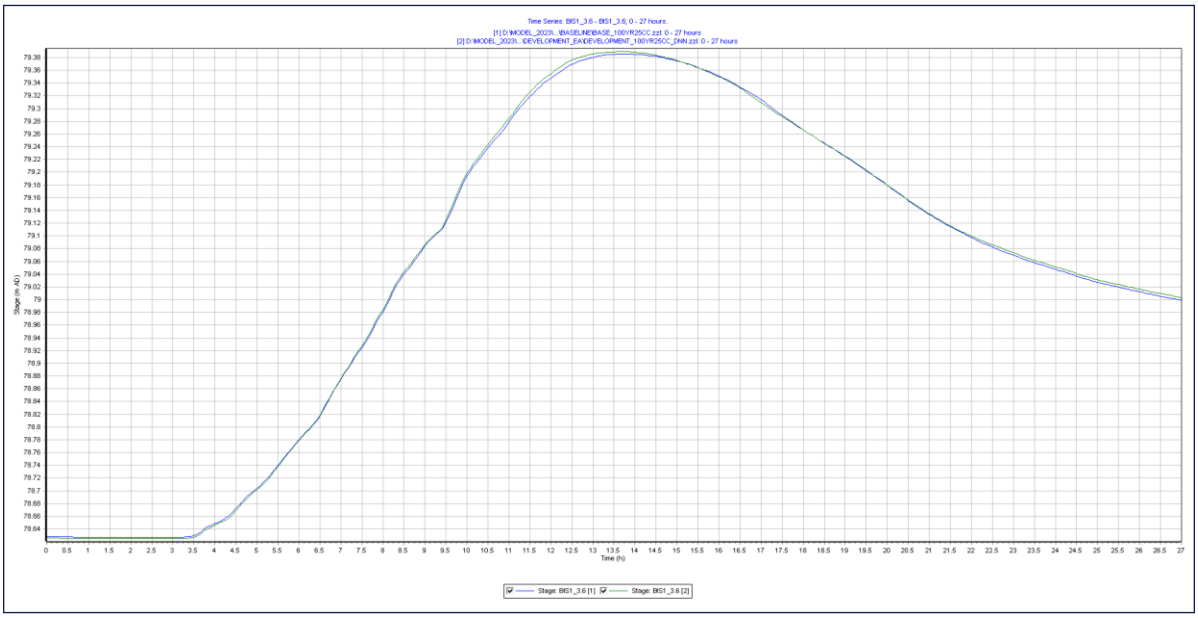


Figure 7-4: Baseline versus Development Stage -Time for 1 in 100yr +25%CC

7.13 Detailed flood map depth for all the events in the development scenario are located in **Appendix D**.

8 Sensitivity Analysis

8.1 The analysis set out above has considered a variety of scenarios including those that may be considered to represent worst case assumptions. Nevertheless, further sensitivity analyses have been undertaken using the baseline hydraulic model to assess the potential changes in water levels as a result of changing various parameters within the model adding even further to its robustness The parameters altered in the model for the sensitivity test are those which are typically most influential on water levels, in particular:

- Roughness for the river channels and floodplains (+/- 20% roughness);
- Downstream boundary model (+/-20% downstream boundary gradient);
- Downstream water level

8.2 The sensitivity runs have been undertaken with the 1 in 100-year return period flood event. The changes in water levels have been assessed at 6 locations, within the watercourse and floodplain.

8.3 Location 1 is positioned in the floodplain area along the North watercourse, location 2 is positioned along the eastern watercourse within the development site, location 3 is along the East watercourse, location 4 is positioned within the floodplain located just before the crossing of Lords Lane, location 5 is positioned along the West watercourse and location 6 is positioned at the downstream section in Bicester.

8.4 Locations of the sensitivity results extractions is illustrated at **Figure 8-1** below.

Figure 8-1: 1 in 100 year Return Period Baseline Maximum Flood Depth

Sensitivity to Manning's Roughness

8.5 The sensitivity to Manning's roughness assesses possible changes within channel conditions as well as its associated floodplain. Any changes in the riverbed, floodplain or bank materials, including hydraulic structures or areas of growth or removal of vegetation.

8.6 As stated before the Ven Te Chow (1959) Manning's n for open channel has been selected in this report.

8.7 The baseline roughness selected are shown in Section 5.27 and are considered to be robust.

8.8 A 20% increase and decrease in Manning's n roughness values were applied to the baseline model in both river channel and floodplain. The resultant changes in peak water levels are presented in **Table 8-1** below.

Location	Baseline 1% AEP	1% AEP +20% Roughness		1% AEP -20% Roughness	
	Water level (m AOD)	Water level (m	Difference (m)	Water level (m	Difference (m)
1	90.235	90.247	0.012	90.22	-0.015
2	84.956	84.993	0.037	84.913	-0.043
3	80.274	80.318	0.044	80.238	-0.036
4	79.501	79.544	0.043	79.468	-0.033
5	81.11	81.146	0.036	81.068	-0.042
6	79.298	79.38	0.082	79.232	-0.066

Table 8-1: Manning's Roughness Sensitivity – Water Level Comparison

8.9 The results in **Table 8-1** demonstrates that the water levels increase between 12mm and 82mm depending upon the location, demonstrating that the increases in roughness can impact the water levels within the watercourse.

8.10 The flood depths decrease at the upper sections of the watercourse, this is most likely due to the low roughness at the watercourse helps convey the water and reduces flood levels within the channel.

8.11 The flood extents for the roughness scenarios show that the increase in roughness will increase the flood extent marginally and mostly in floodplain areas, and the reduction in roughness values reduces the flood extent. However, this is mostly noticed within the floodplain downstream before the Lords Lane crossing.

8.12 The flood extent is marginally smaller for the Manning's -20% in comparison with the Baseline model.

8.13 Detailed flood map comparisons for Manning's "n" sensitivity analysis are presented in **Appendix E**.

Sensitivity to Downstream Boundary

8.14 The sensitivity to the downstream boundary assesses the variations of downstream water levels (if tributary or tidal) as well as variation in gradient within the watercourse and how this can affect the water levels at the development site.

8.15 The downstream boundary has been applied using the normal depth in 1d and 2d domains - Head Discharge-Q (HQ), the downstream slope has been calculated and set as 0.0015 (1 in 666).

8.16 A 20% increase and decrease in downstream boundary values were applied to the Baseline model. The changes in peak water levels are presented in **Table 8-3**.

Location	Baseline 1% AEP	1% AEP +20% BC		1% AEP -20% BC	
	Water level (m	Water level (m	Difference	Water level (m	Difference (m)
1	90.235	90.235	0	90.235	0
2	84.956	84.957	0.001	84.956	0
3	80.274	80.275	0.001	80.274	0
4	79.501	79.482	-0.019	79.526	0.025
5	81.11	81.111	0.001	81.111	0.001
6	79.298	79.26	-0.038	79.353	0.055

Table 8-2: Sensitivity with Downstream Boundary – Water Level Comparison

8.17 The results in **Table 8-3** demonstrates that the water levels within the channel does affect certain sections of the floodplain at the upstream section of Lords Lane up to 25mm and at the downstream boundary up to 55mm.

8.18 The sensitivity analysis for downstream boundary with +20% and -20% shows that there is no difference in the water levels at the upper sections of the watercourse.

8.19 Detailed flood maps comparison for downstream boundary sensitivity analysis are presented in **Appendix E**.

Sensitivity to Downstream Water Level

8.20 This is an extremely worst case scenario to understand the variations in water levels of the upper section of the model depending on the water levels at the downstream watercourse (Bicester section).

8.21 The model received by the EA show that at the upper section of the model the maximum water levels are 78.519m AOD for 1 in 100yrCC and 78.737mAOD for the 1 in 1000yr.

8.22 This scenario represents a constant water level at the downstream section of 78.8mAOD.

8.23 **Figure 8-2** below illustrates the downstream water level curve modelled for this scenario.

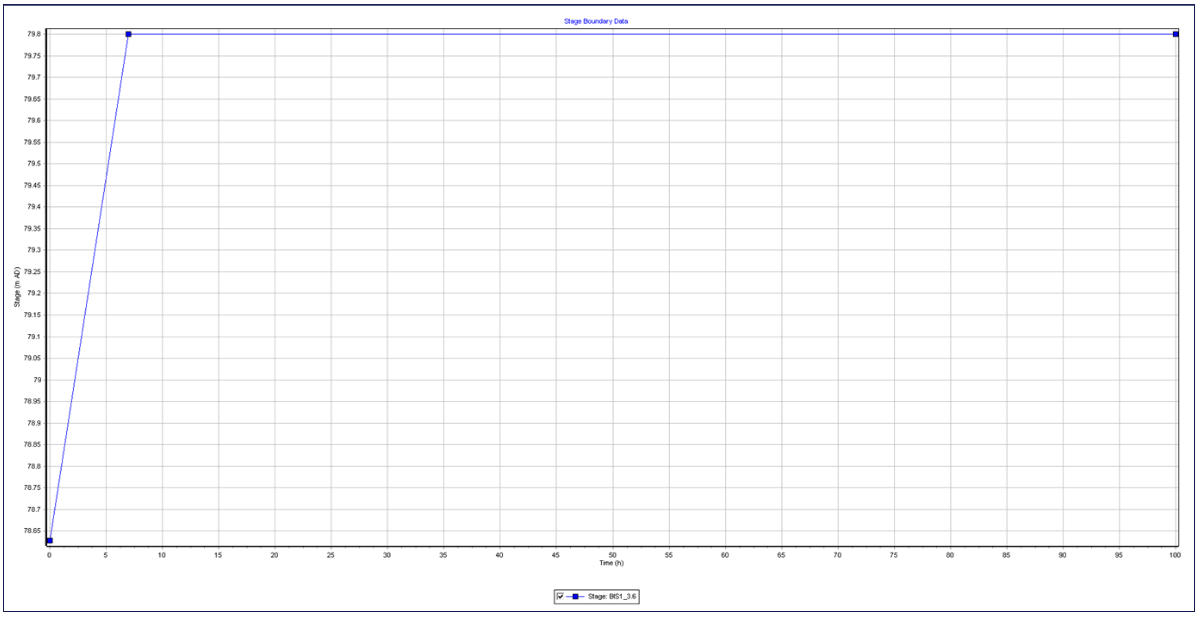


Figure 8-2: Downstream Stage versus time boundary condition

8.24 A water level of 78.8m AOD is assumed at the downstream boundary on the Baseline model. The changes in peak water levels are presented in **Table 8-4** below.

Location	Baseline 1% AEP	1% AEP with downstream water level at 78.8mAOD	
	Water level (m AOD)	Water level (m AOD)	Difference (m)
1	90.235	90.235	0
2	84.956	84.957	0.001
3	80.274	80.274	0
4	79.501	79.848	0.347
5	81.11	81.111	0.001
6	79.298	79.801	0.503

Table 8-3: Sensitivity with Downstream Water Level – Water Level Comparison

8.25 The sensitivity analysis for the floodplain water level demonstrates that between the locations 1, 2,3 and 5 there is no to minimum variations of less than 1mm. However, for the floodplain upstream Lords Lane the flood difference is up to 347mm and for the downstream section up to 503mm.

8.26 As the water level downstream is unusually high and constant during the whole simulation (higher that the levels calculated in the EA's model) the downstream section and floodplain upstream Lords Lane show a substantial increase in water levels. However, as shown in the Table 8-3 upper sections of the watercourse are barely affected.

8.27 The baseline vs sensitivity Downstream Water Level scenario is illustrated at **Figure 8-3.**

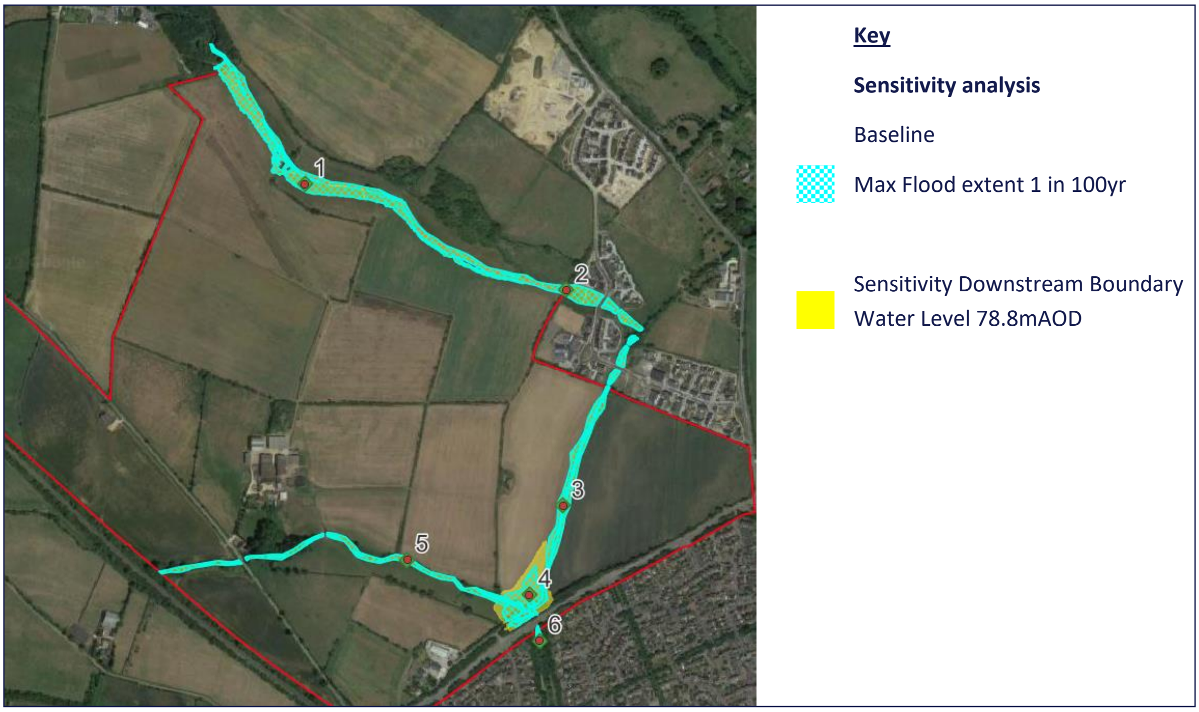


Figure 8-3: Maximum flood extent, Baseline versus Sensitivity Downstream Water Level

Sensitivity Analysis Conclusions

8.28 The sensitivity analysis demonstrates that the model is susceptible to small changes, as a result of changes in Manning's roughness, increasing the water levels at the floodplain and within the watercourse. Thus meaning, a reduction in water levels occurs with a decrease of the roughness values. Such changes are not significant.

8.29 The survey and site visits helped to select the adequate Manning's n number, a choice between the normal and maximum parameter of the range in order to have a conservative but reliable results. Therefore, it is considered that the Manning's n numbers selected for the baseline and subsequent scenarios are both robust and conservative for the modelling, as this was carefully selected.

8.30 Also the sensitivity analysis demonstrates that the water levels at the floodplain may affect the flood extent at the floodplain. However, the upper sections of the watercourse is not affected.

8.31 The sensitivity analysis for downstream water level show that the unusual and unlikely scenario of a water level up to 78.8 at the downstream section will mostly impact the low lying areas at Lords Lane floodplain. However, no additional flood extent anywhere else was observed.

9 Blockage Analysis

9.1 The blockage scenario follows on from the sensitivity analysis and it is used to determine the flood risk at the development area in case of blockage of the bridge located at Lords Lane. This structure is the connection between the watercourse section and the downstream section flowing towards Bicester.

9.2 The section of the East watercourse modelled with 1D Flood Model Pro, a blockage unit was located at the upstream section of the bridge and the assumption is that the bridge will be partially 75% obstructed and reducing the flows downstream.

9.3 Hydraulic model blockage location is illustrated on **Figure 9-1**.

Figure 9-1: Hydraulic Model Extent and Blockage Structure Location

9.1 The blockage scenario has been simulated with 1 in 100yr event.

9.2 The structure is modelled as a bridge, the dimensions of the bridge are set as follows:

- 6.3m width
- 1.25m height
- Total Area 7.8m^2
- 0.035 Manning's coefficient roughness

9.3 Due to the size of the culvert and the area that drains the sub catchment, it is highly unlikely to get totally blocked. However, reduction in conveyance due to the growth of vegetation is considered as one of the possible consequences, although this would not occur as a result of the proposed development.

9.4 TA comparison of the he 75% blockage scenario versus baseline scenario has been undertaken and the differences in peak water levels are presented in **Table 9-1**.

Location	Baseline Water level (m AOD)	Blockage Water level (m AOD)	Difference (m)
1	90.235	90.235	0
2	84.956	84.957	0.001
3	80.274	80.274	0
4	79.501	79.622	0.121
5	81.11	81.111	0.001
6	79.298	79.295	-0.003

Table 9-1: Blockage Scenario – Water Level Comparison

9.5 The blockage scenario demonstrates that the upstream section will store more flood water with water levels reaching depths 121mm greater compared with the baseline close to the bridge.

9.6 The blockage scenario for 1 in 100yr shows additional flood risk as the blockage increases the flood levels at the floodplain at the upstream section of Lords Lane.

9.7 The baseline vs 75% blockage scenario is illustrated at **Figure 9-2**.

Figure 9-2: Maximum flood extent, Baseline versus 75% blockage scenario.

9.8 Detailed flood maps comparison for blockage scenario are presented in **Appendix F**.

10 Summary of Findings

10.1 The baseline modelling shows that the proposed residential development and Site access is not affected by flooding from the onsite watercourses.

10.2 The development scenario demonstrates that it does not affect any third party land increasing flow or flood extent anywhere else nor downstream at Bicester.

10.3 The sensitivity analysis demonstrates that the development site is not affected by variations in roughness within the watercourse, and floodplain. The changes in downstream boundary conditions affect the downstream section and the floodplain at Lords Lane. However the flooding water remain contained within the low lying areas and does not affect the development area.

10.4 The modelling work completed demonstrates that the development can be delivered safely in line with best practice without any increase in downstream or upstream flood risk.

11 Disclaimer

11.1 The conclusions and recommendations contained herein are limited to those given the general availability of background information and the planned usage of the site.

11.2 Third party information has been used in the preparation of this report, which Brookbanks, by necessity assumes is correct at the time of writing. While all reasonable checks have been made on data sources and the accuracy of data, Brookbanks accepts no liability for same.

11.3 The benefits of this report are provided solely to Hallam Land Management Ltd for the proposed development at Land at North West Bicester only.

11.4 Brookbanks excludes third party rights for the information contained in the report.

Appendix A – Topographic Survey

Appendix B – Modelling Results

Appendix C – Sensitivity Analysis

Appendix D – Blockage Analysis

Head Office Address
6150 Knights Court,
Solihull Parkway,
Birmingham Business Park,
Birmingham.
B37 7WY

T +44(0)121 329 4330
brookbanks.com