JBA consulting

Hydraulic Modelling study at land off Sacheverall Way in Groby, Leicestershire

A1-C02

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This report describes work commissioned by Jenny Brader, on behalf of Bloor Homes East Midlands by an email dated 1st August 2024. Harry Wightman and Megan Cruise of JBA Consulting carried out this work.

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Abbreviations

1D	One Dimensional
2D	Two Dimensional
AEP	Annual Exceedance Probability
CC	Climate Change
DTM	Digital Terrain Model
EA	Environment Agency
FEH	Flood Estimation Handbook
FFL	Finished Floor Levels
FRC	Fixed Runoff Coefficient
Ha	Hectares
ICM	Integrated Catchment Modelling
JBA	Jeremy Benn Associates
LIDAR	Light Detection and Ranging
m AOD	Metres Above Ordnance Datum
NaFRA2	National Flood Risk Assessment 2
NGR	National Grid Reference
OS	Ordnance Survey
ReFH	Revitalised Flood Hydrograph

Definitions

Term	Definition
Annual Exceedance Probability	The probability of an event size (often described in terms of peak flow rate) being equalled or exceeded in any one year
Flood risk	A combination of the statistical probability of a flood event occurring and the scale of the consequences if it does. So high risk can include circumstances that might not occur very frequently but have very substantial consequences, and also circumstances that occur relatively frequently and have more moderate consequences, causing relatively frequent but less severe harm
Manning's *n*	This is a roughness coefficient first introduced by Irish Engineer Robert Manning in 1889, which represents the roughness or friction affecting the flow of water by the surface (e.g. channel) over which the water flows. The rougher the surface the greater the effect of friction on the flow.

Executive Summary

JBA Consulting were commissioned by Bloor Homes East Midlands to undertake a detailed hydraulic modelling study in relation to a site located at Sacheverell Way, Groby, Leicestershire.

The purpose of the study is to refine and accurately assess the surface water flood risk to the site. To achieve this, a hydrological assessment was carried out to derive rainfall hyetographs and a 2D InfoWorks-ICM direct runoff hydraulic model was produced to allow the detailed representation of flood depths, flood levels and hazard within the site boundary.

The model was simulated for the following Annual Exceedance Probability (AEP) events: 3.3%, 3.3% with (+35%) climate change, 1%, 1% with (+40%) climate change, and 0.1% storm, for the 60-minute critical (summer) storm duration.

The baseline model results indicate that:

- Flooding is predicted to occur within the site during all modelled design events.
- Flooding is predicted to occur within the site during the 3.3% AEP with (+35%) climate change and 1% AEP with (+40%) climate change events.
- Peak modelled flood depths of up to 1.29m are predicted to occur within the site during the 100-year (1% AEP) plus climate change event.
- Peak modelled flood levels are predicted to range between 84.29m AOD to the north-east and 78.92m AOD towards the southern boundary of the site during the 100-year (1% AEP) plus climate change event.
- Hazard classification areas of ‘caution’ extend across the site, with areas of ‘Danger for most’ to ‘Danger for all’ located within the confines of the formal defences.
- Sensitivity testing of the model found that within the site boundary the model results are insensitive to changes in modelled roughness, and slightly sensitive to changes in the fixed runoff coefficient (runoff percentage) value.

The post-development model results indicate that:

- Raising the ground levels around the culvert inlet and redirecting the overland flow paths into a swale during the 1% AEP with (+40%) climate change event decreases modelled flood depths to third-party land at the south of the site.
- When comparing depths to the baseline scenario, the northeast of the site, where the ground modification is located, shows a significant increase in depths of +10cm due to ground level raising in order to divert the overland flow paths. There is a significant reduction south of the modification, which shows the diversion of overland flow paths from this area.

Recommendations

The results of the hydraulic modelling can be used to inform the Flood Risk Assessment for the site. However, it is recommended that the hydraulic modelling is reviewed and validated by the Lead Local Flood Authority.

It is recommended that the post-development scenario of the model is altered during the detailed layout design and that Finished Floor Levels (FFLs) are set above the modelled design flood level with freeboard is applied. It is recommended that the new levels be re-simulated in the hydraulic model to understand the impact on flood levels and flood hazard within the site, along with the incorporation of a site surface water drainage strategy.

The model results have been prepared for the purpose of quantifying surface water flood risk at the site and surrounding area. If the results are intended to be used for surface water flood risk mapping of the wider catchment, further model refinement is recommended. Additionally, if further data is made available it is recommended that the model is updated to improve the representation of surface water flood risk parameters.

1 Introduction

1.1 Terms of Reference

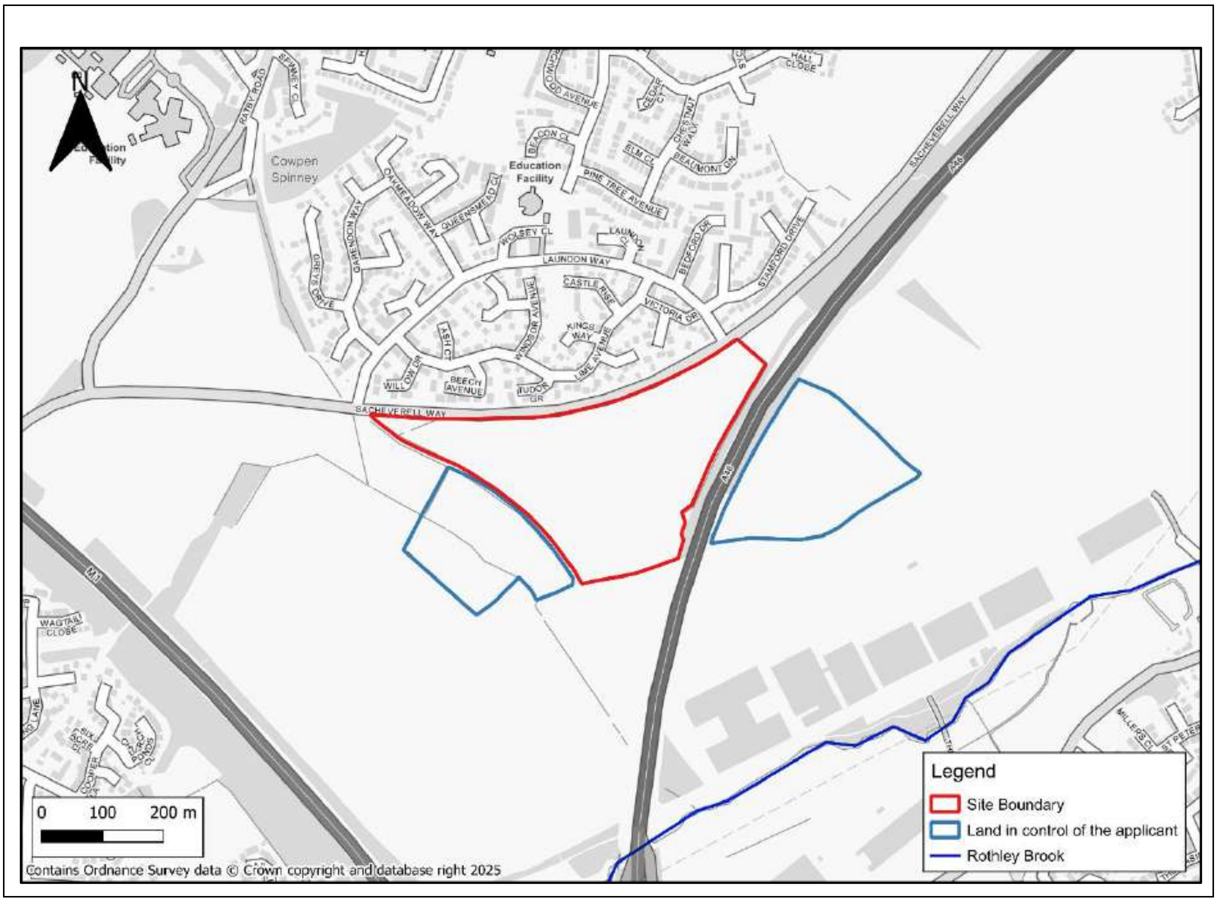
JBA Consulting were commissioned by Bloor Homes East Midlands to undertake a detailed hydraulic modelling study in relation to a site located off Sacheverall Way, Groby, Leicestershire (hereafter referred to as 'the site').

The purpose of the study is to refine and accurately assess the surface water flood risk to the site. To achieve this, a 2D InfoWorks-ICM direct runoff hydraulic model was produced to allow the detailed representation of flood depths, flood levels and hazard within and around the site boundary.

1.2 Site details

Table 1-1: Site details

Site address	Sacheverall Way, Groby, Leicestershire
Site area	10.55ha
Existing land-use	Greenfield land
OS NGR	SK 52595 06329
County	Leicestershire
Country	England



1.3 Site description

The site is located south of Sacheverall Way, Groby. Agricultural land-uses make up the majority of the site. Located north and south-west to the site are large residential areas, which are both bounded by the M1 motorway and the A46. The catchment itself is mostly rural. Analysis of LiDAR elevation data shows the topography of the location slopes from the north-east to the south-west. There are several drainage ditches in the vicinity of the site and a presumed culvert running through the centre of the site. All drainage ditches are presumed to be draining into Rothley Brook, designated as an Environment Agency (EA) Main River, approximately 400m south-east of the site.

Analysis of existing surface water risk mapping, OS mapping and LIDAR elevation data indicates that the site topography slopes south-westerly towards the Rothley Brook tributary as shown in Figure 1-1.

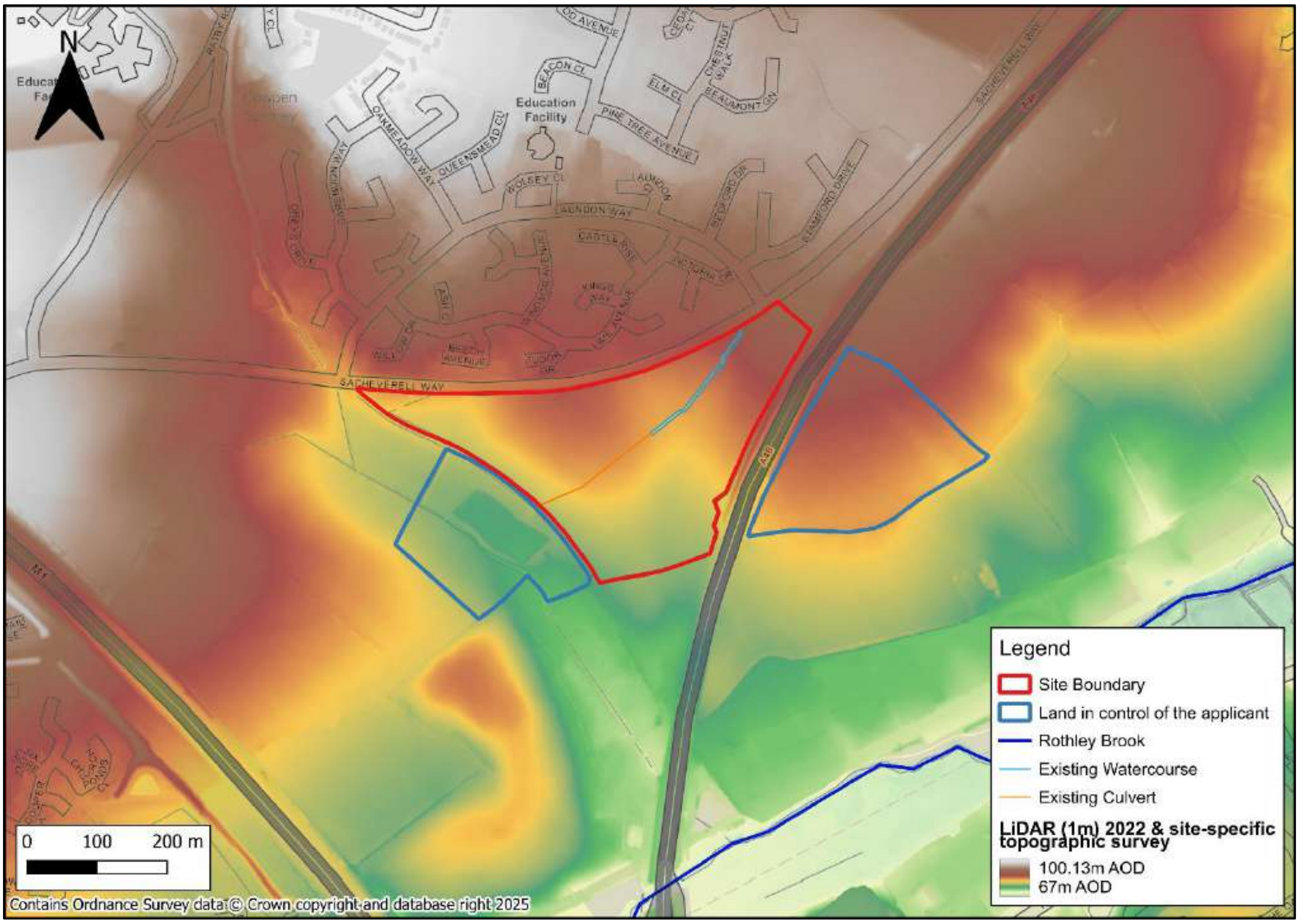


Figure 1-1: Site Topography

1.4 Existing flood data

The EA's NaFRA2 mapping for the site is shown in Figure 1-2.

The mapping indicates that the site is at risk from surface water flooding in the 3.3% AEP, 1% AEP and 0.1% AEP events. The main cause of flooding is suggested to be flow routes originating from the catchment of Rothley Brook, which is located on the southern boundary. However, these maps originate from broad-scale modelling techniques whereby the capacity public sewers, channel and the structures crossing it is approximated. Key structures including the upstream surface water public sewer network, and surface water features which may allow water to drain away in lower return period events, (such as culverts, drains, gullies, kerbs, etc.) are unlikely to be explicitly represented.

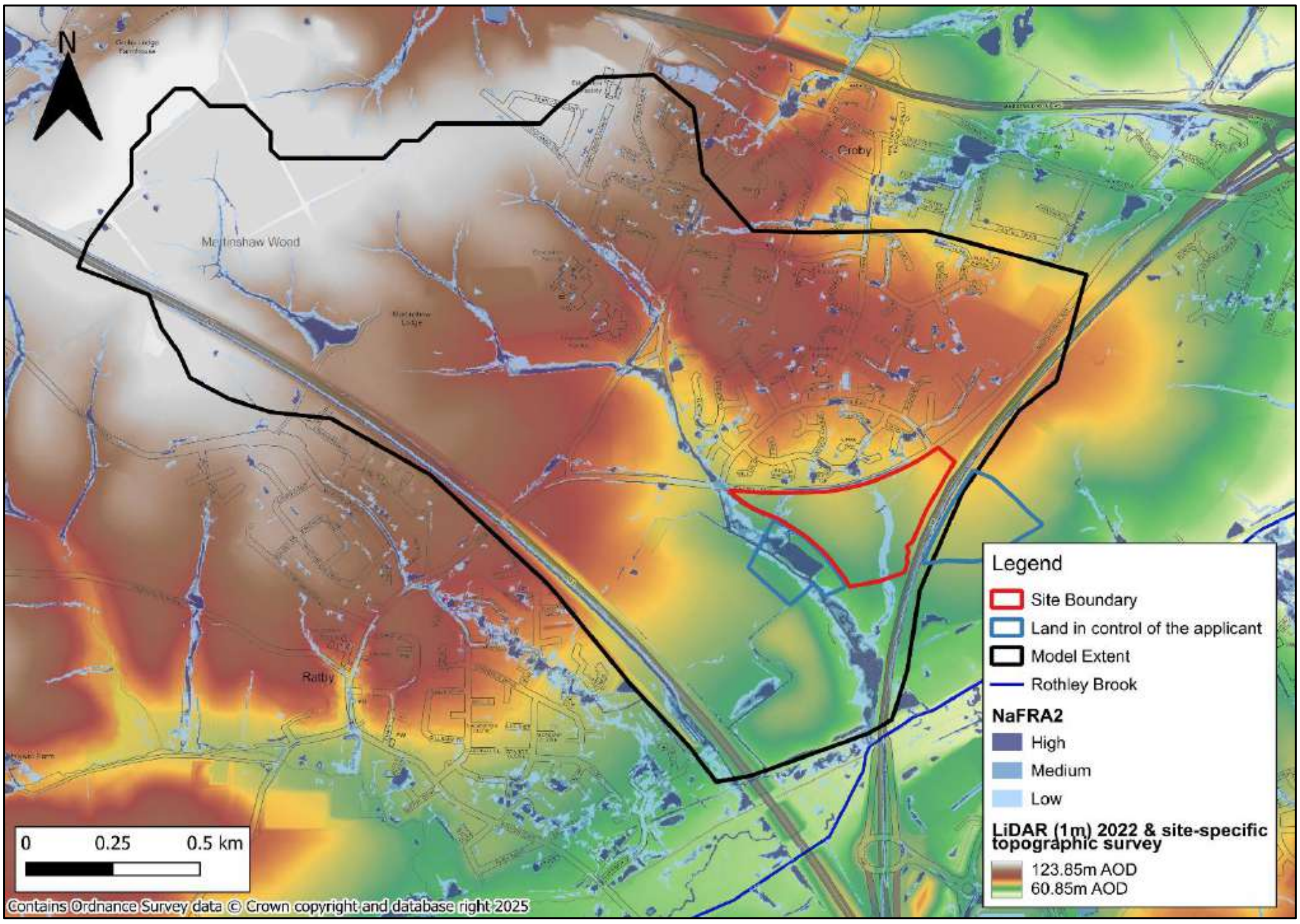


Figure 1-2: Environment Agency's Risk of Flooding from Surface Water Mapping

1.5 General modelling approach

A direct rainfall-runoff model was developed to refine the understanding of surface water flood risk at the site, incorporating local surface water drainage information and topographic data to improve upon the EA's Risk of Flooding from Surface Water mapping.

A 2D model was developed in InfoWorks ICM covering the study catchment draining towards the site. Rainfall hyetographs were derived for the following storm events:

- 3.3% AEP and 3.3% AEP with (+35%) climate change uplift.
- 1% AEP and 1% AEP with (+40%) climate change uplift.
- 0.1% AEP.

The rainfall hyetographs were applied directly to the model surface to provide baseline model results, including flood depths, flood levels and hazard in the vicinity of the site.

The hydraulic model sensitivity to roughness values and the fixed runoff coefficient was tested to improve confidence in the model results.

2 Approach

2.1 Data availability

Amber Utilities Ltd were commissioned to undertake a culvert information survey report within the vicinity of the site in October 2024 (see Appendix A). The survey consisted of one culvert identified within the vicinity of the site. Sewer maps covering the area around the site were obtained from Severn Trent Water (see Appendix C) and used to inform the representation of the public sewer network, to the north and north-east of the site.

Topographic survey of the site was collected in July 2020 by Urban Contours and was available for use in this study (See Appendix B). The topographic survey was used within the modelling to represent levels throughout the site. Environment Agency LiDAR data was obtained from the Open Data website and used within the modelling to represent ground levels within the wider catchment. The LiDAR data used has a grid resolution of 1m and flown in 2022.

Ordnance Survey (OS) ZoomStack mapping was used to inform land use information in the study catchment.

2.2 Site walkover

A site walkover was carried out by JBA Consulting in September 2024 to improve understanding of drainage features within the site and surrounding area. The visit confirmed the presence of a small watercourse flowing down the western edge of the main field, a flood relief basin in the west of the site and several structures. All structures noted in the topography and drainage drawing, provided by the client, were confirmed on site apart from the culverts along the northern edge of the site which were inaccessible due to heavy vegetation.

2.3 Hydraulic Model Build

The flood modelling approach was based on the "direct rainfall" concept where rainfall is applied to each mesh element in the hydraulic model and routed across the mesh surface, identifying flooding pathways and areas where ponding will occur. A 2D direct rainfall model has been built to refine the EA's NaFRA2 mapping by representing the local drainage network using the available information. The model was built using InfoWorks ICM version 2024.5.

2.4 2D domain

2.4.1 Model extent and topography

The hydraulic model extent encompasses the topographic catchment for the site and that of nearby surface water flow paths identified on the EA's NaFRA2 mapping. It also includes the sewer catchment for the surface water sewer that discharges into the watercourse near the site. The model extent is shown in Figure 2-1.

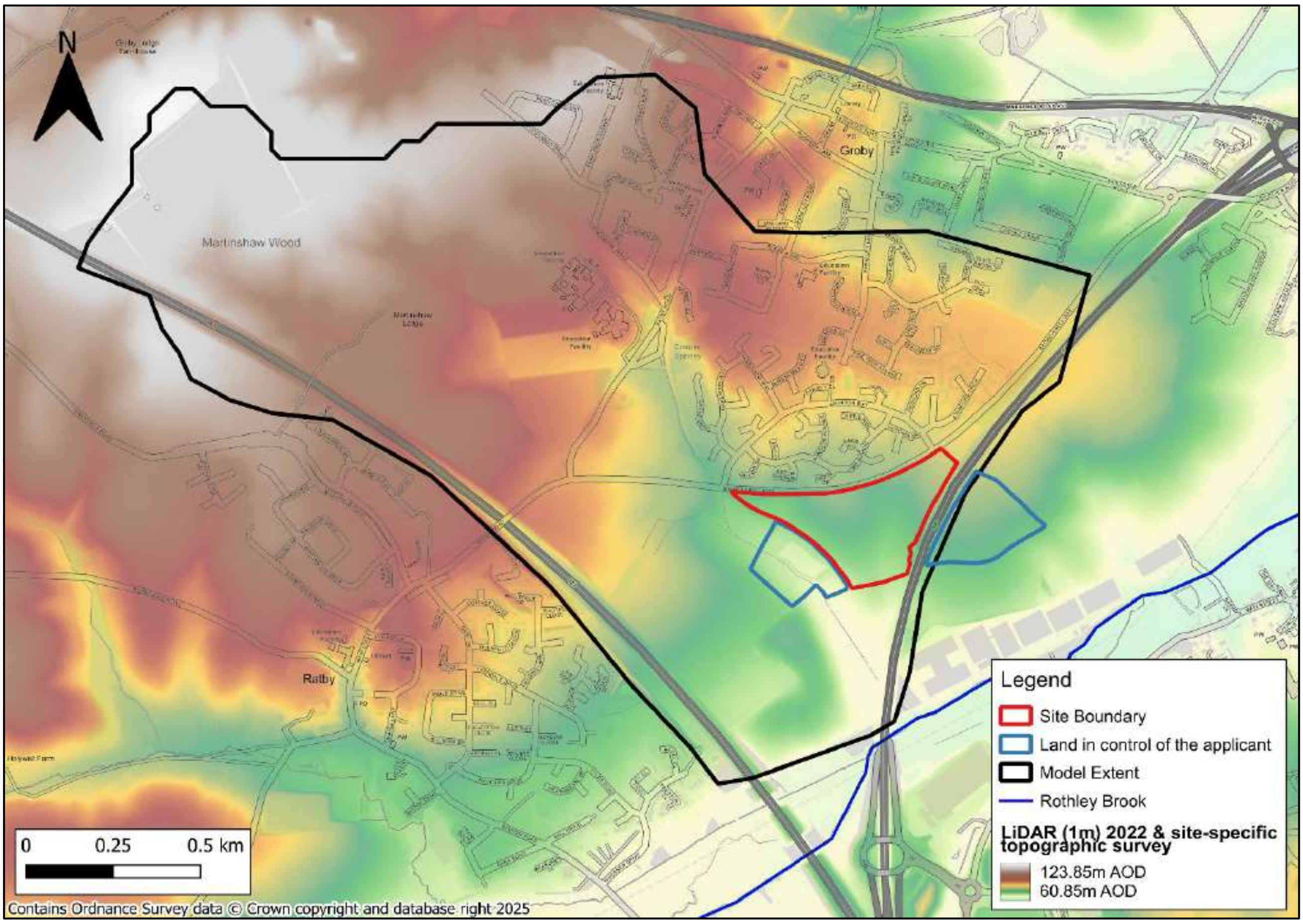


Figure 2-1: Model extent

The 1m Environment Agency 2022 LiDAR has been used to derive the topography throughout the model domain. A maximum triangle size of 10m^2 has been applied to the 2D zone, with terrain sensitive meshing used to increase the resolution in areas of steep topography and improve the representation of changes in the topography. A summary of the key 2D Zone parameters relating to model topography is shown in Table 2-1.

Table 2-1: 2D Zone parameters summary

	Value
Maximum triangle area (m^2)	10
Minimum element area (m^2)	2
Terrain-sensitive meshing	True
Maximum height variation (m)	0.25
Minimum angle (degrees)	25

2.4.2 Model roughness parameters

Manning's *n* roughness values were used to represent the model roughness in the hydraulic model's 2D domain based on land uses across the model extent. Land uses were defined using Ordnance Survey (OS) ZoomStack mapping (see Figure 2-2). Table 2-2 details the range of Manning's *n* values applied to the 2D domain.

Table 2-2: Manning's *n* values within the hydraulic model 2D domain

Land use	Manning's n
General Surface	0.050
Dense woodland	0.100
Roads	0.025
Buildings	0.300
Inland water	0.040

2.4.3 2D features

Mesh zones were used to represent buildings within the 2D domain and raise the mesh to a level 0.125m above the ground level to represent an assumed building threshold. This approach allows buildings threshold levels to be raised above the 2D mesh to account for their impact on overland flows.

Mesh zones were also used to represent roads, enforce kerb lines, and to represent watercourses. Levels were taken from LIDAR with no modifications made.

The 2D features are shown in the 2D model schematic in Figure 3-2.

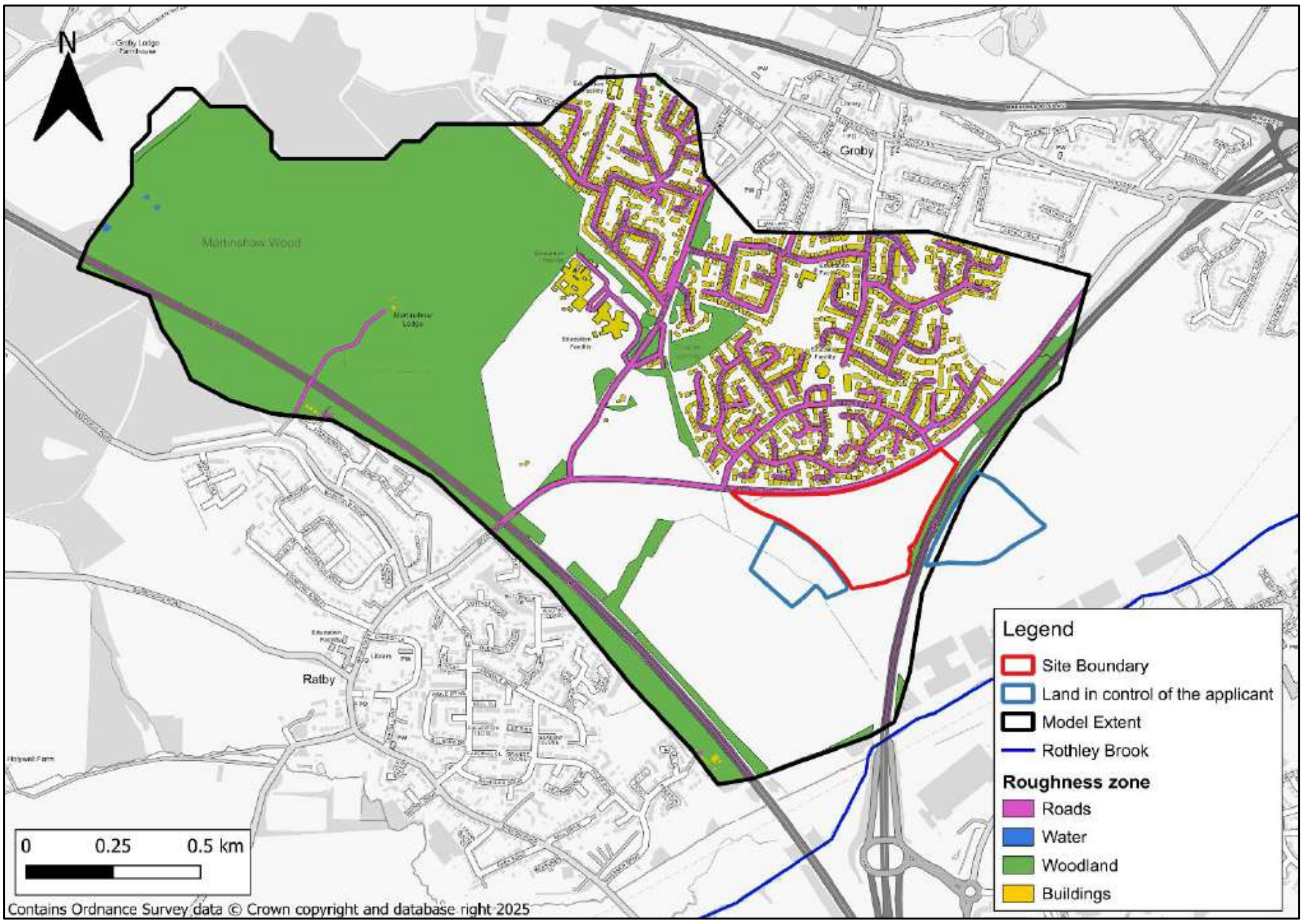


Figure 2-2: 2D model schematic

2.5 1D domain

2.5.1 Representation of sewers

The public surface water sewer network covering the area to the north of the site draining into the modelled drainage ditches via culvert has been represented in the 1D domain with conduits and manholes based on information from the Severn Trent Water sewer maps (see Appendix C).

It was necessary to make some assumptions about data taken from Severn Trent Water sewer mapping including the following:

- Missing pipe dimensions were assumed based on standard pipe sizes and upstream and downstream connections.
- Manholes have been set to have a 2D flood type with those on or close to the highway which uses the weir equation to determine flow between the 1D and 2D domains.
- Ground levels were assumed to be equal to the cover level.
- Manholes were assumed to be unsealed and allowed to surcharge.

- Manholes with unknown dimensions are modelled using the default calculation InfoWorks ICM uses for Chamber plan area: A= $\frac{\pi}{4} \times (Width\ of\ incomming\ pipe + 0.762)^2$

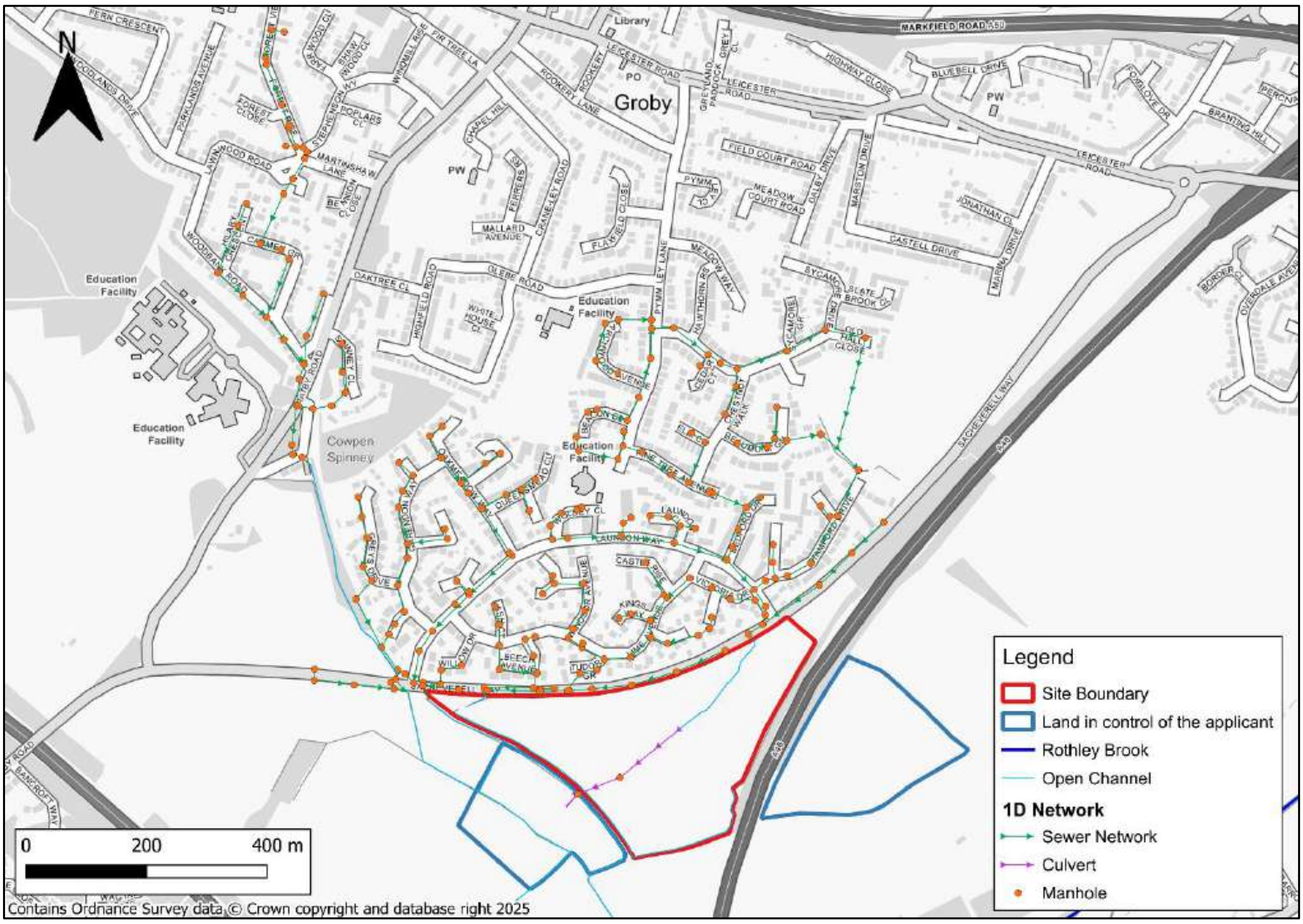


Figure 2-3: 1D model schematic

2.6 Application of hydrology

Rainfall hyetographs were applied directly to the ground model across the catchment using the ReFH2 rainfall generator in InfoWorks-ICM. InfoWorks-ICM allows hyetographs to be automatically generated within the software using catchment rainfall parameters from the FEH service. FEH22 rainfall descriptors were used to generate the rainfall events. An evapotranspiration value of 3mm/day was applied to summer storms to represent summer conditions, and an evapotranspiration value of 1mm/day was applied to winter storms.

Rainfall hyetographs were calculated for the 3.3% AEP (1 in 30-year), 1% AEP (1 in 100-year), and 0.1% AEP (1 in 1000-year) storm events. Storm durations of 1-hour, 3-hours and 6-hours were simulated for each return period with the maximum extent generated for each event determined as the critical storm duration. Winter and summer rainfall were also compared. The results showed that the maximum flood extents at the site occur during the

1-hour storm duration and summer rainfall profile, in all return periods. This event was taken forward as the critical storm duration for all return periods.

The effect of climate change was assessed by increasing the peak rainfall by 35% for the 3.3% AEP event and 40% for the 1% AEP event (upper end allowance for the 2080's epoch from the Loddon and tributaries management catchment).

Rainfall was applied directly to the whole of the 2D model surface, with overland flow routed by surface topography and surface features, such as buildings and roads. Buildings within 50m of the sewer network were represented with subcatchments to route flow into the 1D sewer network, accounting for the drainage of buildings directly into the sewers. Drainage from roads into the sewers was represented using manholes where sewers have been modelled and so were not represented with subcatchments.

Infiltration zones were used to control the volume of rainfall allowed to flow onto the 2D mesh and were also used to account for losses from the 2D domain (e.g. water flowing into the sewer network through subcatchments or water lost through infiltration).

Infiltration surfaces represented in the model are shown in Figure 2-4. Roads and buildings have been given separate infiltration surfaces dependant on whether they have been modelled with a connection to the 1D sewer network or not. If the sewer network draining roads or buildings has not been represented in the model, they have been given a 12mm/hour loss to account for drainage to the sewer network.

In order to prevent any double counting of inflows to the model (by application of rainfall to the 2D mesh and the 1D sewer system using subcatchments) runoff coefficients used to route flows to the sewer system through subcatchments have been reduced based on the 2D runoff coefficient. The fixed runoff coefficients used are shown in Table 2-3.

Table 2-3: Fixed runoff coefficients

Land Use	1D runoff coefficient	2D runoff coefficient	Infiltration surfaces loss (mm/hr)
Roads (No sewer network represented)	-	0.9	12
Buildings (No sewer network represented)	-	1.0	12
Buildings (With sewer network represented)	0.8	0.2	-
Green space	-	0.43	-

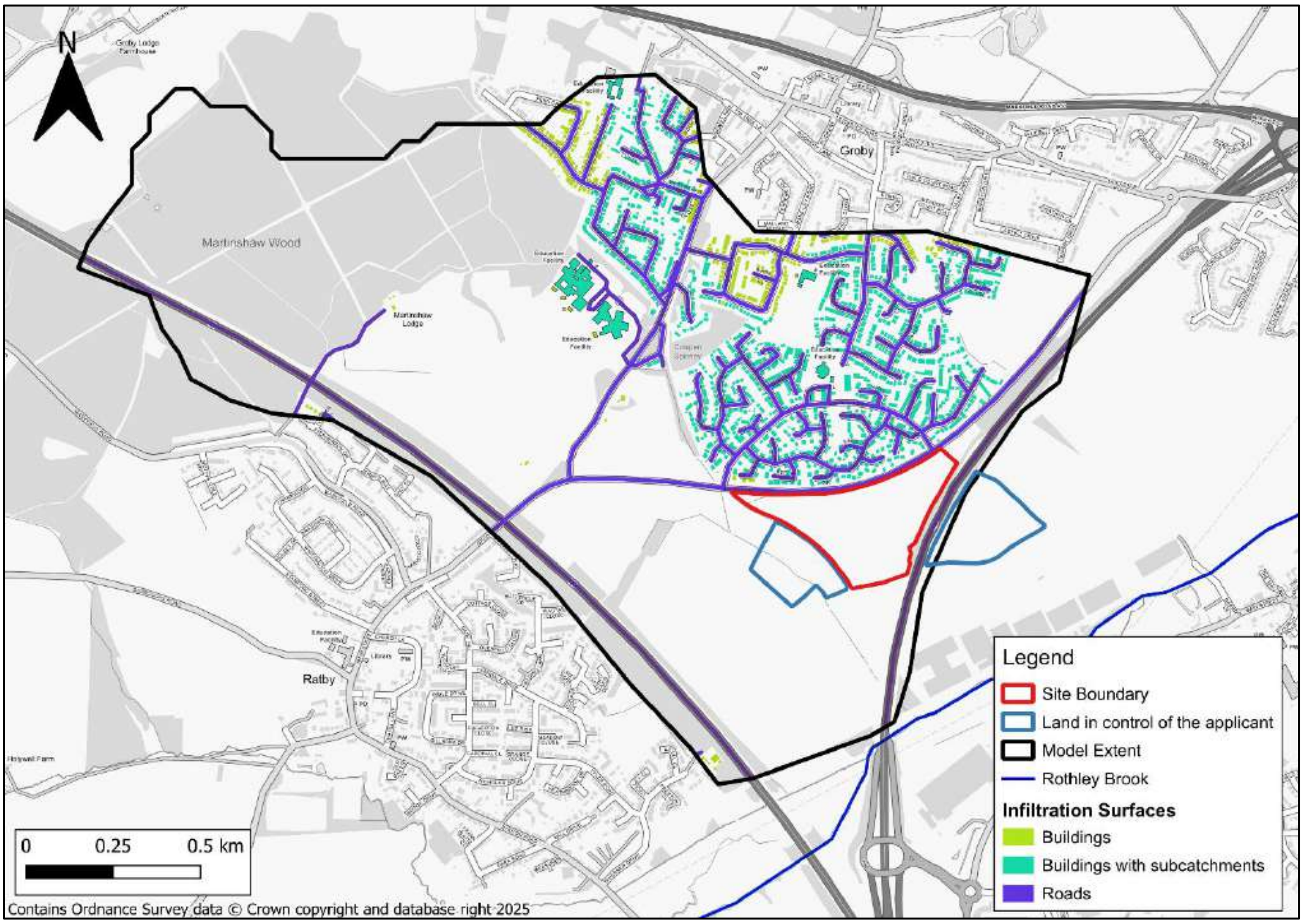


Figure 2-4: Infiltration surfaces

2.7 Calibration

No specific recorded flood levels or flow data were available for the study area. As a result, the model has not been calibrated. Instead, a model validation has been carried out through comparison with the EA's NaFRA2 mapping (see Section 3).

2.8 Model Runs

The following scenarios were simulated within the model:

Scenario	Return period	Description
Baseline scenario	3.3% AEP (30-year)	Existing condition scenario
Baseline scenario	3.3% AEP (30-year) with (+35%) climate change	Existing condition scenario
Baseline scenario	1% AEP (100-year)	Existing condition scenario
Baseline scenario	1% AEP (100-year) with (+40%) climate change	Existing condition scenario
Baseline scenario	0.1% AEP (1,000-year)	Existing condition scenario
Post-development scenario (Option 3)	1% AEP with (+40%) climate change	Post-development modelling
Sensitivity analysis	1% AEP (100-year)	20% increase in roughness
Sensitivity analysis	1% AEP (100-year)	20% decrease in roughness
Sensitivity analysis	1% AEP (100-year)	20% increase in fixed runoff coefficient
Sensitivity analysis	1% AEP (100-year)	20% decrease in fixed runoff coefficient

2.9 Sensitivity analysis

The model's sensitivity to changes in roughness and fixed runoff coefficient were assessed. Further detail on the sensitivity testing is provided in Appendix D.

Sensitivity testing of the model found that within the site boundary the model results are insensitive to changes in modelled roughness, and slightly sensitive to changes in the fixed runoff coefficient (runoff percentage) value.

3 Model validation

To assess the validity of the model results, the surface water modelling results were compared with the EA's NaFRA2 maps for one return period.

3.1 Comparison with the EA 1 in 100-year surface water flood map

Figure 3-1 shows the EA's 1% AEP NaFRA2 extent compared to the 1% AEP surface water extent modelled as part of this study. The flood extents within the site for the modelled 1% AEP event are predicted to be smaller compared to that of the 1% AEP NaFRA2 in the southwest of the site. The predicted decrease in flooded area within the site can be attributed to the representation of the sewer network, inclusion of site-specific topography and improving the resolution of the modelling.

At the east of the site, it is shown that there is no risk of flooding from surface water however, there is a risk of flooding in the modelled extent. This is due to the inclusion of a culvert immediately downstream of the extent within the model, which the Environment Agency's modelling does not explicitly represent in their NaFRA2 mapping.

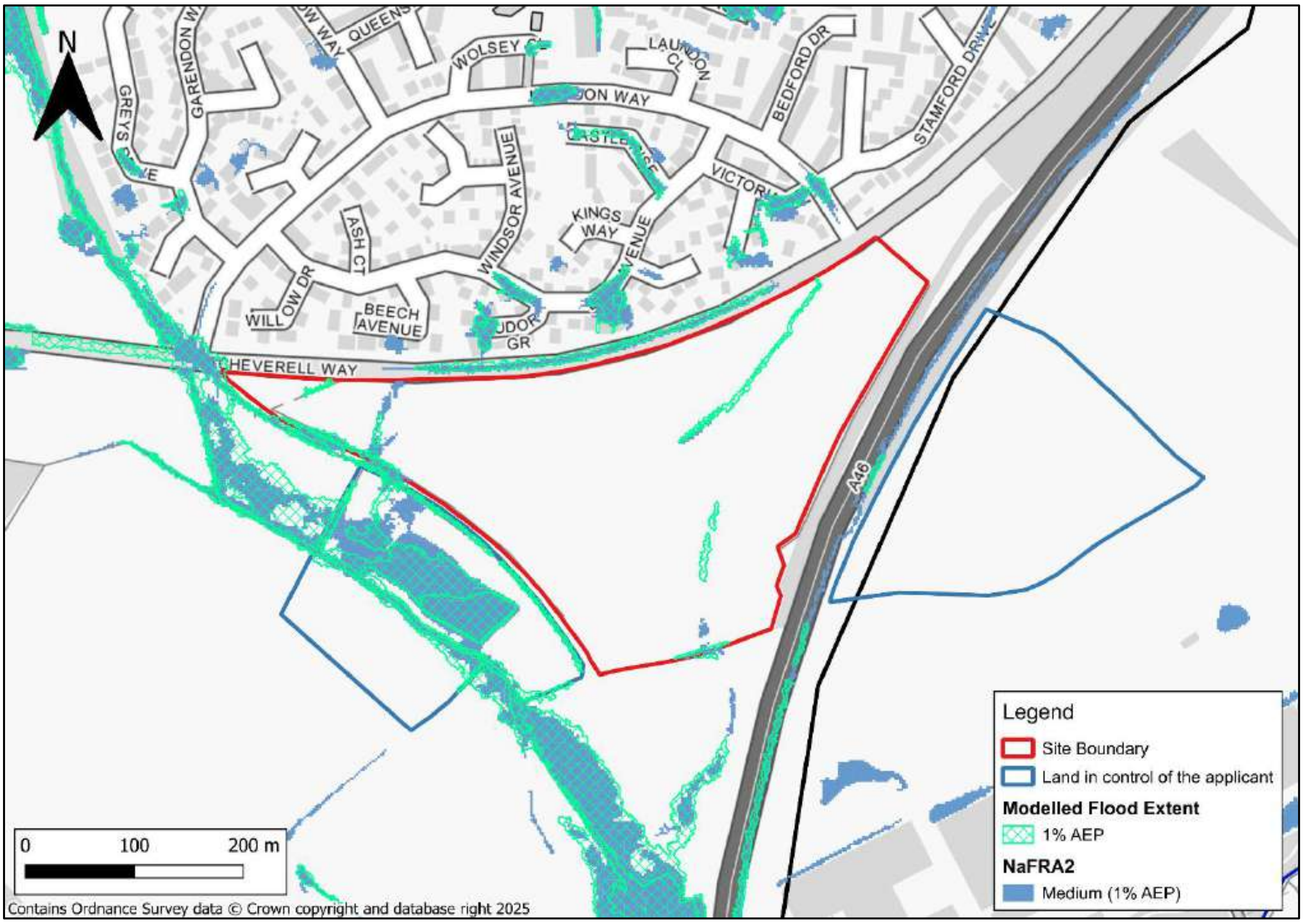


Figure 3-1: 1% AEP comparison with NaFRA2

4 Hydraulic model results

4.1 Processing of hydraulic model results

The following processing steps, aligned with those taken from the EA's National Scale Surface Water Flood Mapping Methodology[1], have been applied to the outputs of all hydraulic modelling results:

- Filtered to remove areas where Hazard to People rating is less than 0.575
- Filled areas with an area less than $50m^2$
- Removal of polygons with an area less than $100m^2$.

Only 2D model results are included in these figures.

4.2 Existing conditions / baseline scenarios

4.2.1 Peak flood extents

Flood extents for the 3.33% AEP, 1% AEP and 0.1% AEP flood events are shown in Figure 4-1, with mapping for the 3.33% AEP with (+35%) climate change and 1% AEP with (+40%) climate change events shown in Figure 4-2.

Figure 4-1 indicates that flooding is predicted to occur within the site during all modelled events.

Figure 4-2 indicates that flooding is also predicted to occur within the site during the 3.3% AEP with (+35%) climate change and 1% AEP with (+40%) climate change events.

1 https://www.gov.uk/government/publications/flood-risk-maps-for-surface-water-how-to-use-the-map/risk-of-flooding-from-surface-water-understanding-and-using-the-map#how-the-rofsw-map-was-created

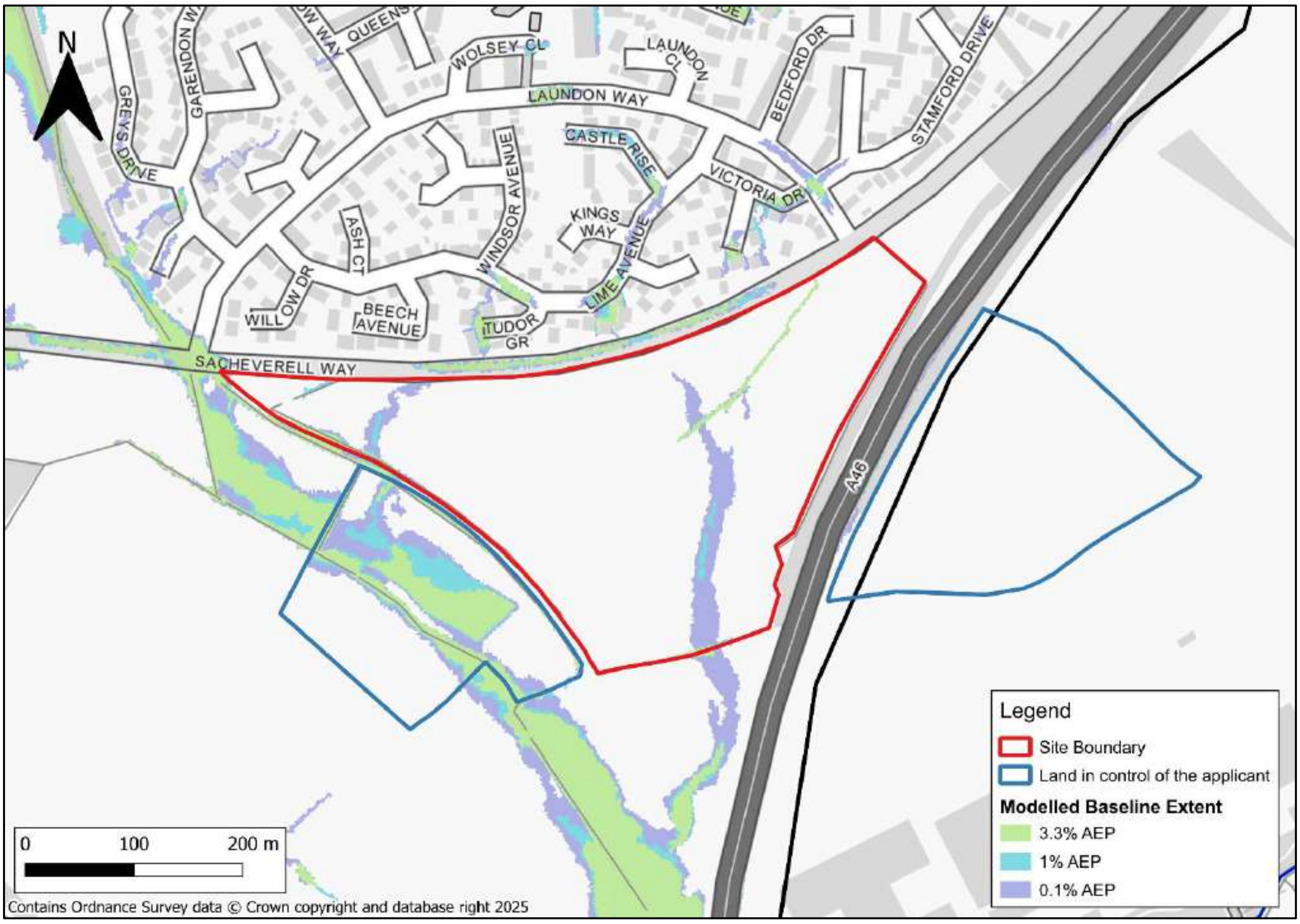


Figure 4-1: Baseline scenario peak flood extents

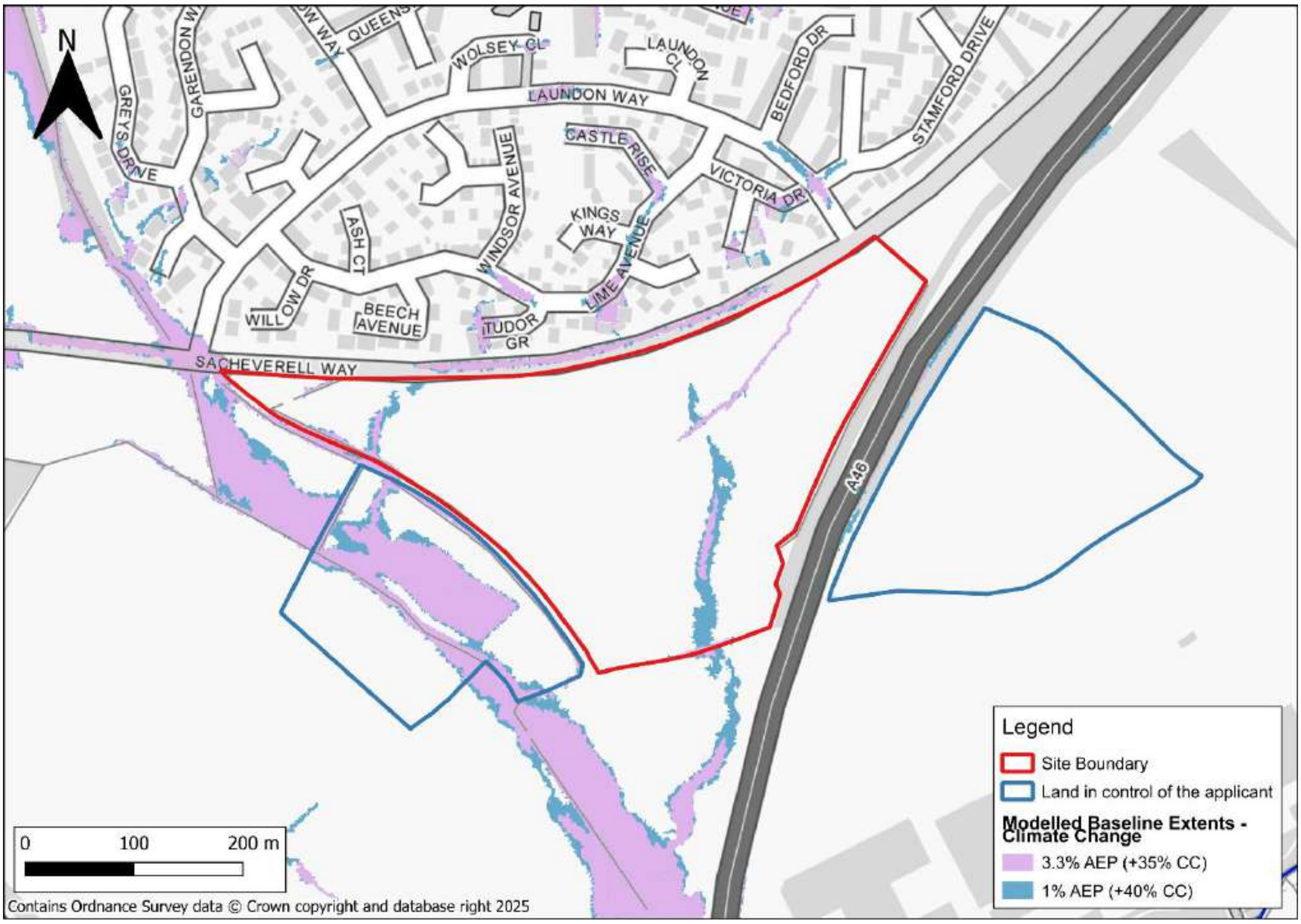


Figure 4-2: Baseline scenario climate change peak flood extents

4.2.2 Peak flood depths

Figure 4-3 shows the peak flood depths within the site boundary during the 1% AEP with (+40%) climate change event for the baseline scenario. Peak modelled flood depths of up to 0.99m are predicted to occur within the site during the 100-year (1% AEP) plus climate change event. The deepest areas of flooding are shown to be confined within the drainage channels running from northwest to southeast, along the western boundary of the site and northeast to southwest through the centre of the site.

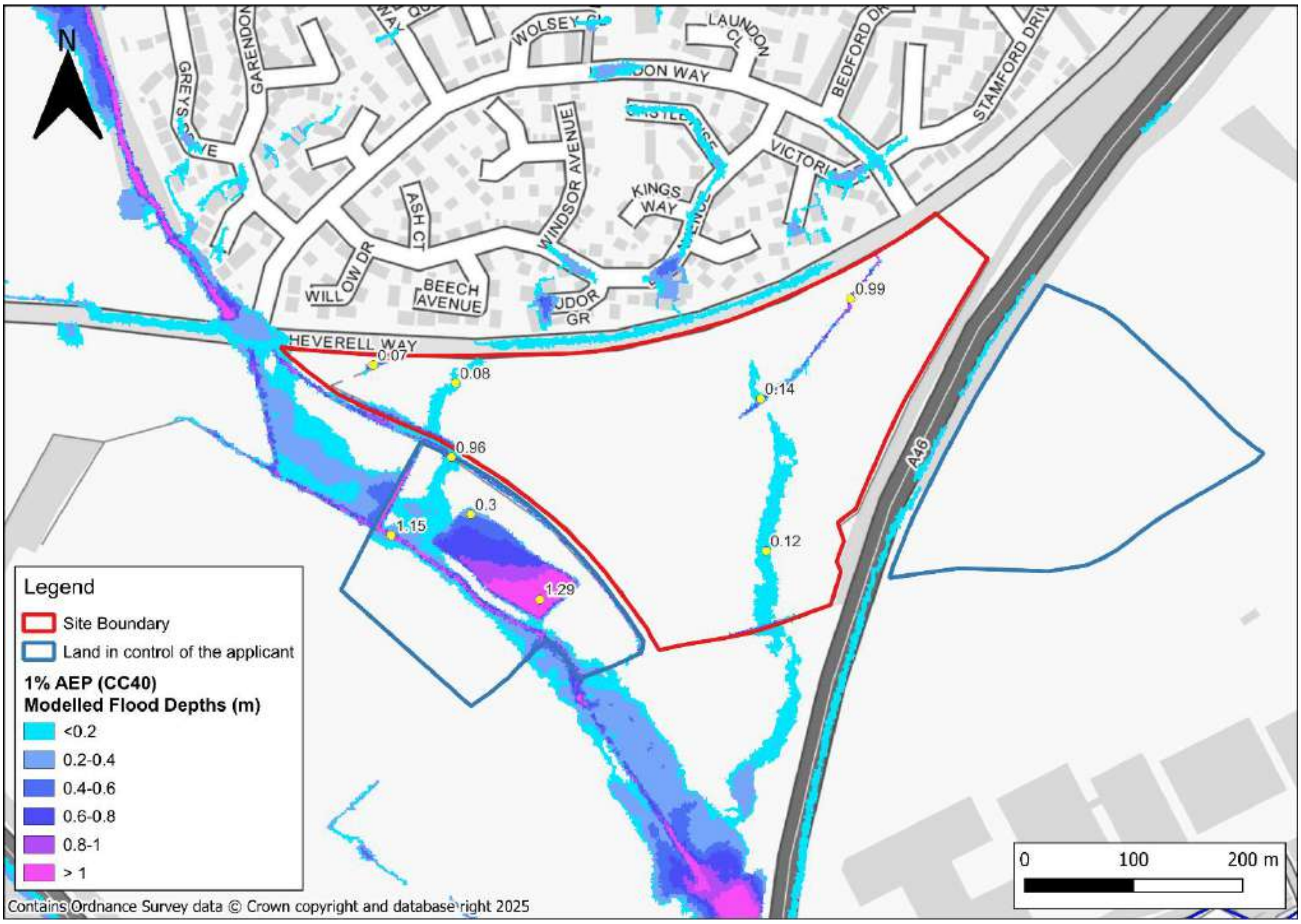


Figure 4-3: Modelled depths in 1% AEP with (+40%) climate change flood event

4.2.3 Peak flood levels

Figure 4-4 shows the peak flood levels within the site boundary during the 1% AEP with (+40%) climate change event for the baseline scenario. Peak modelled flood levels are predicted to range between 84.29m AOD to the north-east and 78.92m AOD towards the southern boundary of the site during the 100-year (1% AEP) plus climate change event.

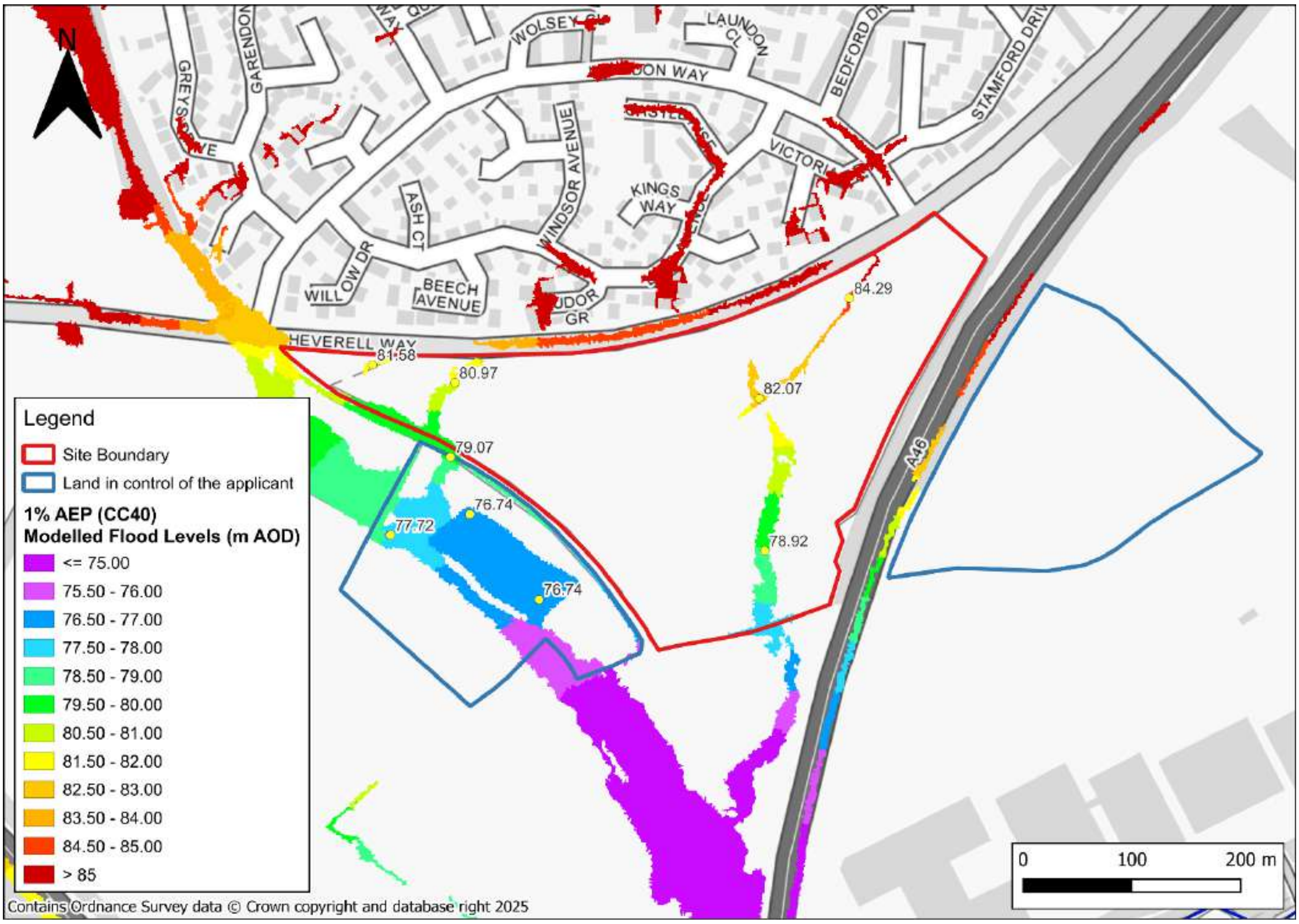


Figure 4-4: Modelled levels in the 1% AEP with (+40) climate change flood event

4.2.4 Hazard to people

The hazard-to-people rating has been mapped using the formula as specified in Defra's FD2320/TR2 "Flood Risk to People". The different hazard categories are shown in Table 4-1 and the hazard classification to the site during the 100-year (1% AEP) plus 40% climate change event is shown in Figure 4-5.

Table 4-1: Defra's FD2320/TR2 "Flood Risks to People" classifications

Flood hazard rating	Degree of Flood Hazard	Description
<0.75	Caution	Caution *"Flood zone with shallow flowing water or deep standing water"*
0.75 to 1.25	Moderate	Dangerous for some (i.e. Children) *"Danger: flood zone with deep or fast flowing water"*
1.25 to 2.00	Significant	Dangerous for most *"Danger: flood zone with deep fast flowing water"*
>2.00	Extreme	Dangerous for all *"Extreme danger: flood zone with deep fast flowing water"*
Using the hazard equation HR = d*(v+0.5) + DF Where d = depth of flooding (m) v = velocity of floodwaters (m/sec) DF = debris factor		

Figure 4-5 shows that during the 100-year (1% AEP) plus 40% climate change event. The site is mostly comprised of areas of 'caution', with only these classification areas located on the edge of the eastern and western boundaries. There are a few areas along the southwest of the site that are a 'danger for most' in regions within the confines of the drainage ditches and the flood relief basin. Along the most south-western drainage ditch, there is a 'danger for all' classification, which stretches across the site boundary.

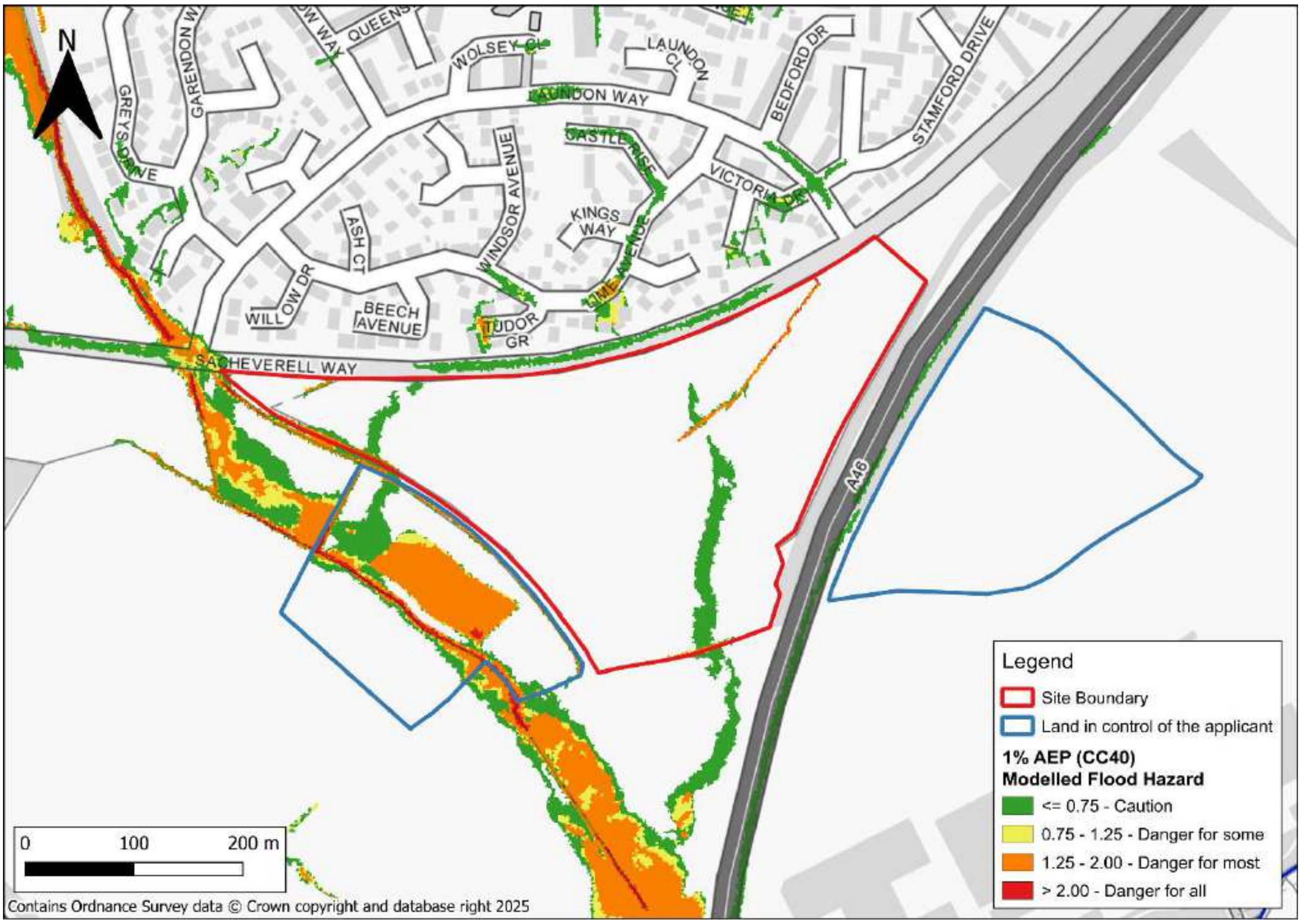


Figure 4-5: Baseline scenario peak flood hazard – 1% AEP plus 40% climate change

4.3 Post-development modelling

A post-development model scenario was developed and was tested for the 1% AEP with (+40%) climate change event. The post-development model scenario is shown in Figure 4-6

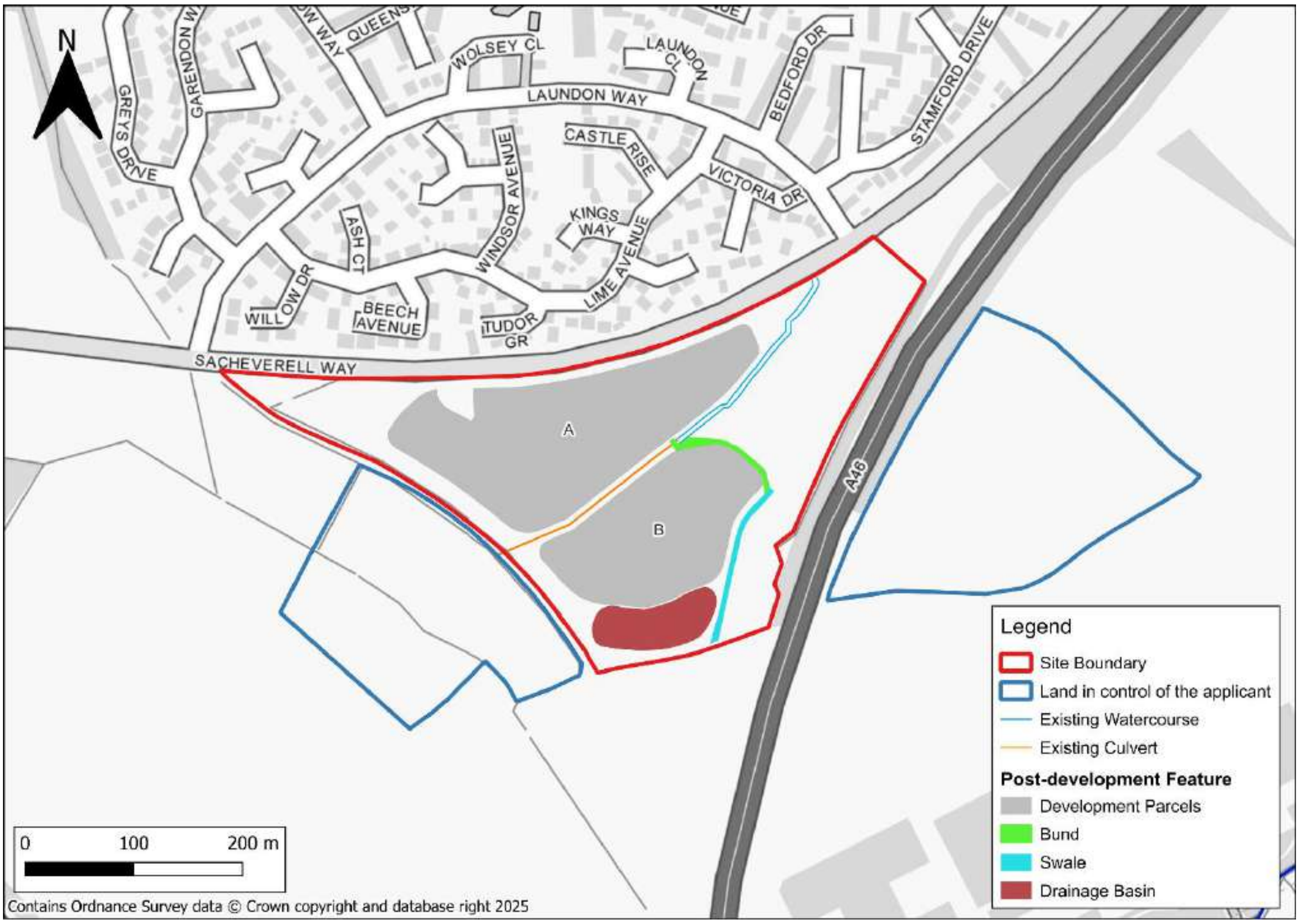


Figure 4-6: Post-Development model scenario

The baseline model was amended by applying proposed ground level changes, including a swale to redirect high flows previously entering the onsite culvert. To facilitate this, ground levels were raised around the culvert inlet, ensuring that when water levels reached 81.6 m AOD, the excess flows could be redirected eastward into a swale designed to channel the water southwards. The existing 900 mm culvert has been reduced to 750 mm to represent the installation of a 750 mm orifice plate at its inlet. This measure aims to lower the proposed downstream flood risk and redirect overland flow through the swale into the drainage ditch along the site's northern boundary.

Further to discussions with the LLFA on the 17th December 2024, it was confirmed that If the existing culvert running through the site was not daylit, the LLFA would not object to the planning application on the basis that the 'status quo if being maintained'.

Indicative development parcels are shown in Figure 4-6. Rainfall inputs were removed from the areas shown to represent the impact of the proposed surface water drainage strategy. This post-development scenario aimed to redirect off-site generated overland flow paths southwards around Development Zone B.

4.3.1 Post-development flood depths

The results of the post-development modelling for the 1% AEP with (+40%) climate change event shows that maximum flood depths within the site vary between 0.11m and 0.41m in Figure 4-7.

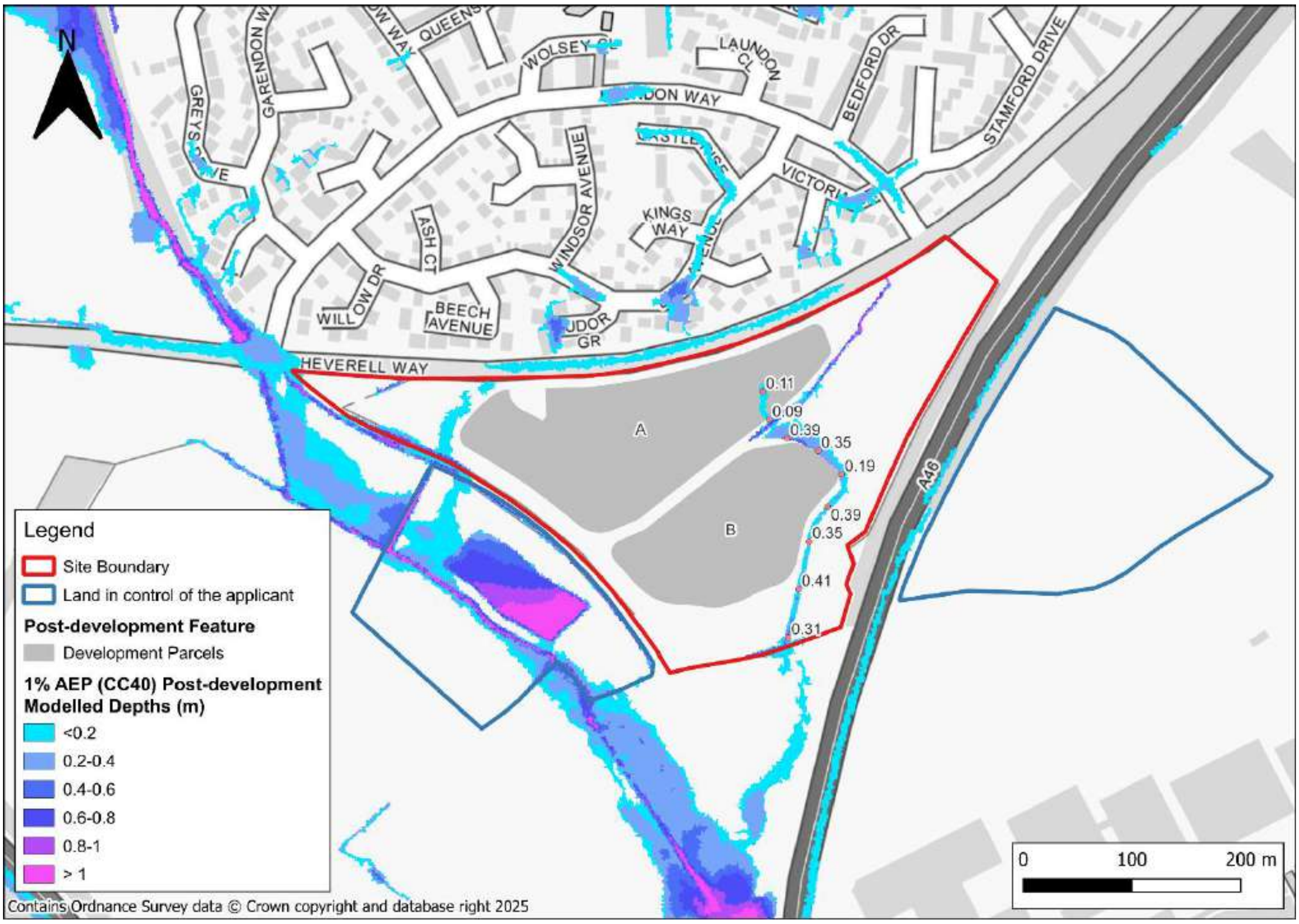


Figure 4-7: Post-development flood depths in the 1% AEP with (+40%) climate change event

4.3.2 Post-development flood levels

Maximum modelled flood levels within the site boundary during the post-development scenario for the 1% AEP with (+40%) climate change event ranged from 82.38m AOD within the central region of the site to 77.9m AOD towards the southern boundary of the site (Figure 4-8).

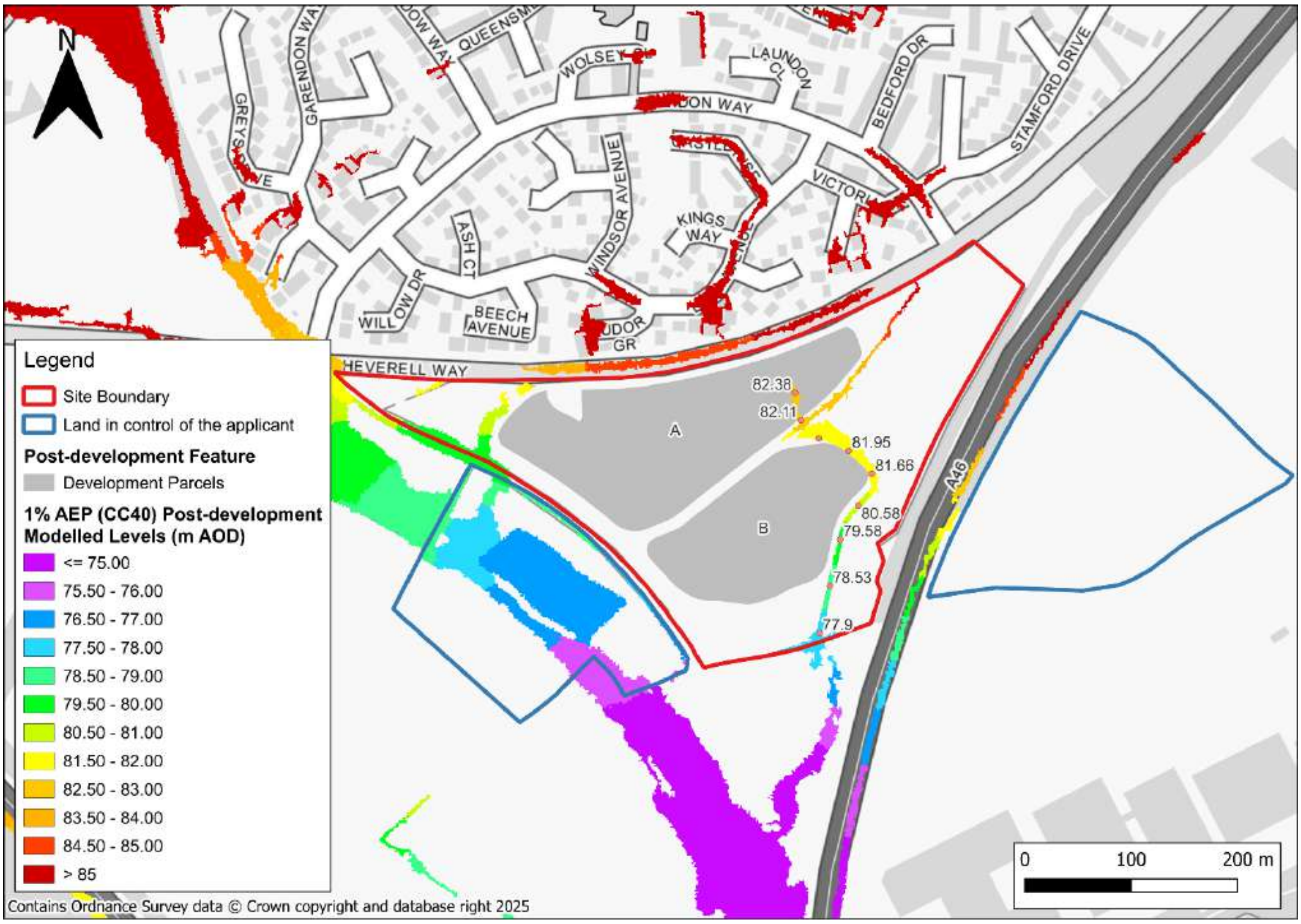


Figure 4-8: Post-development flood levels in the 1% AEP with (+40%) climate change event

4.3.3 Impact of post-development scenario on flood depth

The impact of the post-development model scenario on maximum flood depths has been assessed for the 1% AEP with (+40%) climate change event. The difference between baseline and the post-development maximum flood depths is shown in Figure 4-9.

Overall, the post-development scenario had no significant impact on flood risk at third-party land. The northeast of the site, where the ground modification is located, shows a significant increase in depths of +10cm due to ground level raising in order to divert the overland flow paths. There is a significant reduction south of the modification, which shows the diversion of overland flow paths from this area.

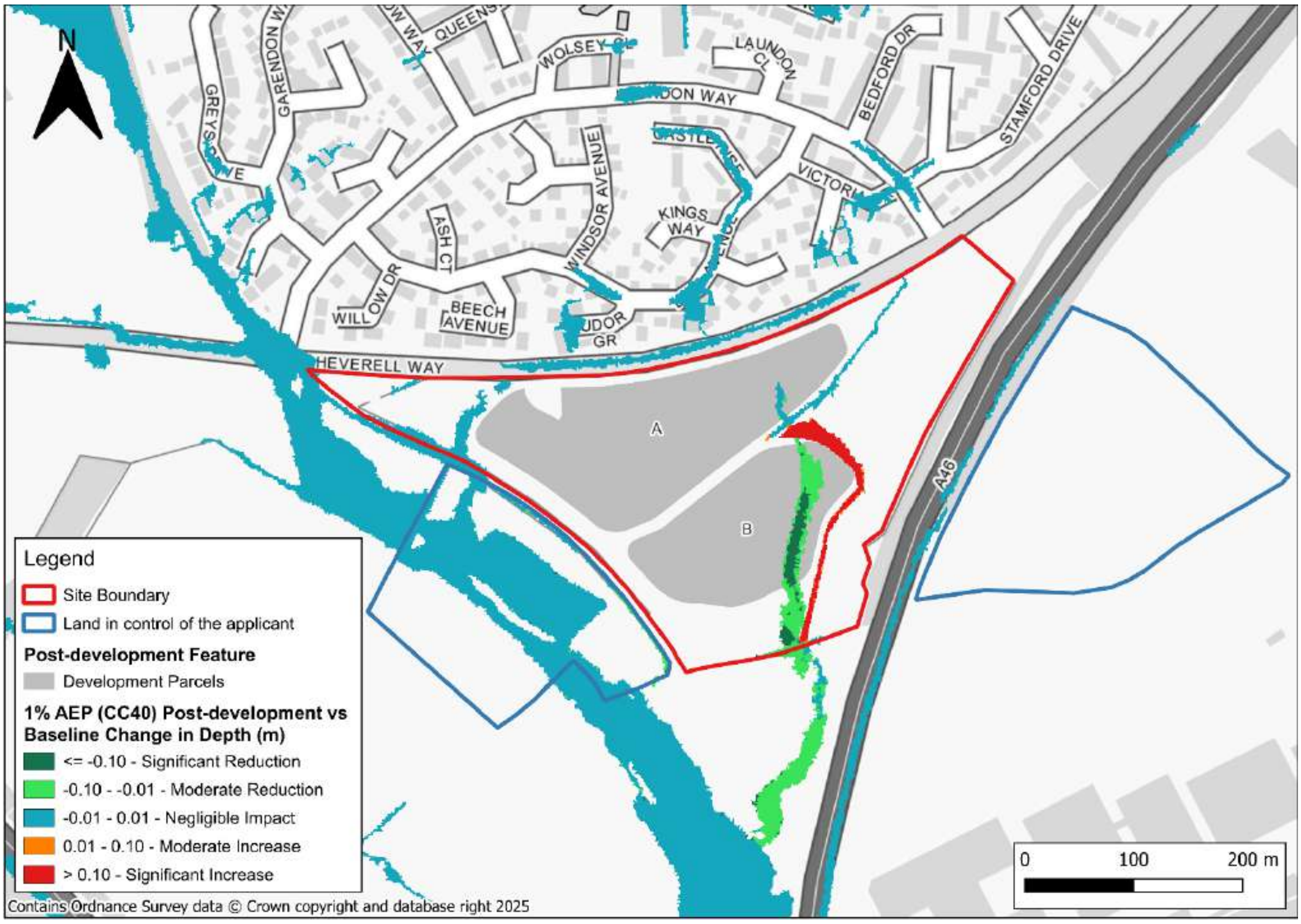


Figure 4-9: Depth comparison between baseline and post-development

4.3.4 Post-development flood hazard

Figure 4-10 shows the post-development hazard rating to the site for the 1% AEP with (+40%) climate change event. The Hazard-to-people rating for the site largely falls within the 'Caution' hazard category, with small, isolated patches along the proposed swale falling into 'Danger for some' and ‘Danger for most’ hazard category. Overall, there is safe access and egress.

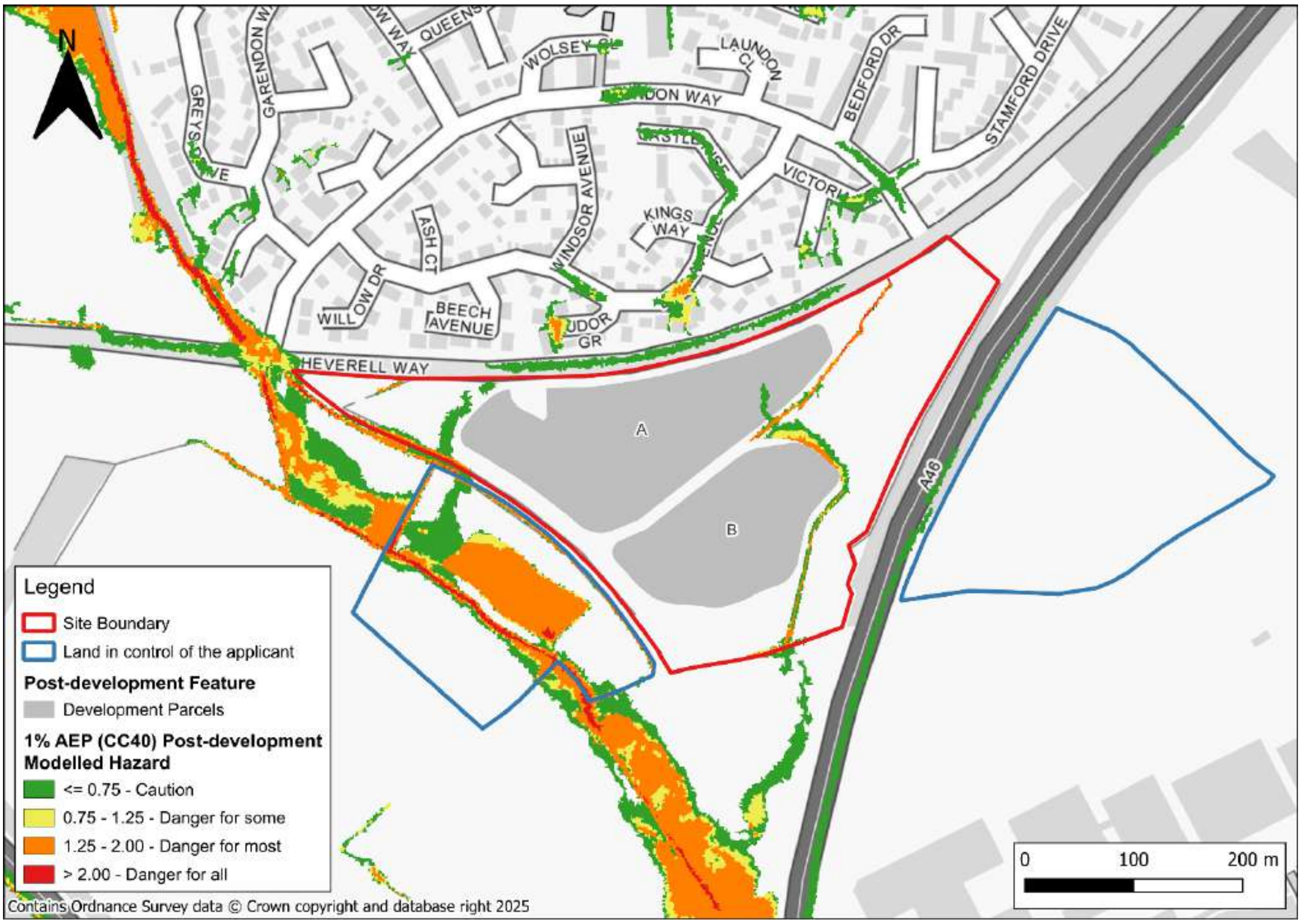


Figure 4-10: Post-development peak flood hazard in the 1% AEP with (+40%) climate change event

5 Model assumptions and uncertainties

5.1 General assumptions/uncertainties

The representation of any complex system by a model requires a number of assumptions to be made. In the case of the 1D elements of the model the following assumptions have been made:

- Model parameters used, such as roughness and structure coefficients, are representative of the general conditions.
- The units used to represent hydraulic structures within the model represent the situation accurately using the information available at the time of the study.
- A stable numerical solution can be achieved.
- The design hydrology accurately represents flows in the models given there was no flow / level data or historical flood data for the catchment available for calibration of flows in the surface water model.
- The watercourse and culverts around the site have been represented as un-silted using hard bed levels.

In terms of the 2D elements of the model the following assumptions have been made:

- The LIDAR and topographic survey are representative of the land surface and no errors have been introduced through filtering algorithms.
- Model parameters used, such as roughness, are representative of the general conditions.
- The losses applied to rainfall accurately represents the amount of runoff that is lost to infiltration and evaporation.

6 Summary and recommendations

6.1 Summary

- Bloor Homes East Midlands commissioned JBA Consulting to assess surface water flood risk in relation to a site located off Sacheverall Way, Groby, Leicestershire.
- A 2D InfoWorks-ICM direct runoff hydraulic model was produced to allow the detailed representation of flood depths, flood levels and hazard within the site boundary.
- The model was run for the 3.3% AEP, 3.3% AEP with (+35%) climate change, 1% AEP, 1% AEP with (+40%) climate change, and 0.1% AEP storm events for the 60-minute critical (summer) storm duration.

The baseline model results indicate that:

- Flooding is predicted to occur within the site during all modelled design events.
- Flooding is predicted to occur within the site during the 3.3% AEP with (+35%) climate change and 1% AEP with (+40%) climate change events.
- Peak modelled flood depths of up to 1.29m are predicted to occur within the site during the 100-year (1% AEP) plus climate change event.
- Peak modelled flood levels are predicted to range between 84.29m AOD to the north-east and 78.92m AOD towards the southern boundary of the site during the 100-year (1% AEP) plus climate change event.
- Hazard classification areas of 'caution' extend across the site, with areas of 'Danger for most' to 'Danger for all' located within the confines of the formal defences.
- Sensitivity testing of the model found that within the site boundary the model results are insensitive to changes in modelled roughness, and slightly sensitive to changes in the fixed runoff coefficient (runoff percentage) value.

The post-development model results indicate that:

- Raising the ground levels around the culvert inlet and redirecting the overland flow paths into a swale during the 1% AEP with (+40%) climate change event decreases modelled flood depths to third-party land at the south of the site.
- When comparing depths to the baseline scenario, the northeast of the site, where the ground modification is located, shows a significant increase in depths of +10cm due to ground level raising in order to divert the overland flow paths. There is a significant reduction south of the modification, which shows the diversion of overland flow paths from this area.

6.2 Recommendations

The results of the hydraulic modelling can be used to inform the Flood Risk Assessment for the site. However, it is recommended that the hydraulic modelling is reviewed and validated by the Lead Local Flood Authority, ideally before developing a masterplan or submitting a planning application.

It is recommended that the post-development scenario of the model is altered during the master planning and that Finished Floor Levels (FFLs) are set above the modelled design flood level with freeboard is applied. It is recommended that the new levels be re-simulated in the hydraulic model to understand the impact on flood levels and flood hazard within the site, along with the incorporation of a site surface water drainage strategy.

The model results have been prepared for the purpose of quantifying surface water flood risk at the site and surrounding area. If the results are intended to be used for surface water flood risk mapping of the wider catchment, further model refinement is recommended. Additionally, if further data is made available it is recommended that the model is updated to improve the representation of surface water flood risk parameters.

Appendices

A Culvert Survey

Topographical Notes

STANDARD REFERENCES

ABBREVIATIONS

bb	belisha beacon	ko	kerb outlet
bl	bollard	lb	light bollard
brw	brick ret. wall	lp	lamp post
bs	bus stop	mh	manhole
bt	telecoms cover	mk	marker post
bw	brick wall	mp	metal post
catv	cable TV cover	np	nameplate (road)
cbf	closeboarded fence	obf	open boarded fence
cbrw	conc block ret. wall	p	post
cbw	conc block wall	pb	post box
cl	cover level	ret.	retaining wall
clf	chainlink fence	re	rodding eye
conc	concrete	rg	road gully
cp	concrete post	rs	road sign
cw	concrete wall	rwp	rainwater pipe
cws	combined sewer	sp	signpost
dk	drop kerb	srw	stone ret. wall
ep	electricity pole	sv	stop valve
ESS	Elec. Sub-Station	svp	soil vent pipe
fb	flower bed	sw	stone wall
fh	fire hydrant	s/w	stay wire
fl	floor level	sws	storm water sewer
fws	foul water sewer	tcb	telephone callbox
g	gully	tl	traffic light
gsv	gas valve	tp	telegraph pole
h/r	hand rail	utr	unable to raise
ic	inspection cover	vp	vent pipe
il	invert level	w'lap	woodlap fence
irf	iron railing fence	wm	water meter
jb	junction box	wp	wood post

KEY FOR UNDERGROUND SERVICES

ABBREVIATION KEY

UTILITY SURVEY NOTES

AMBER UTILITIES LTD

CLIENT: Bloor Homes

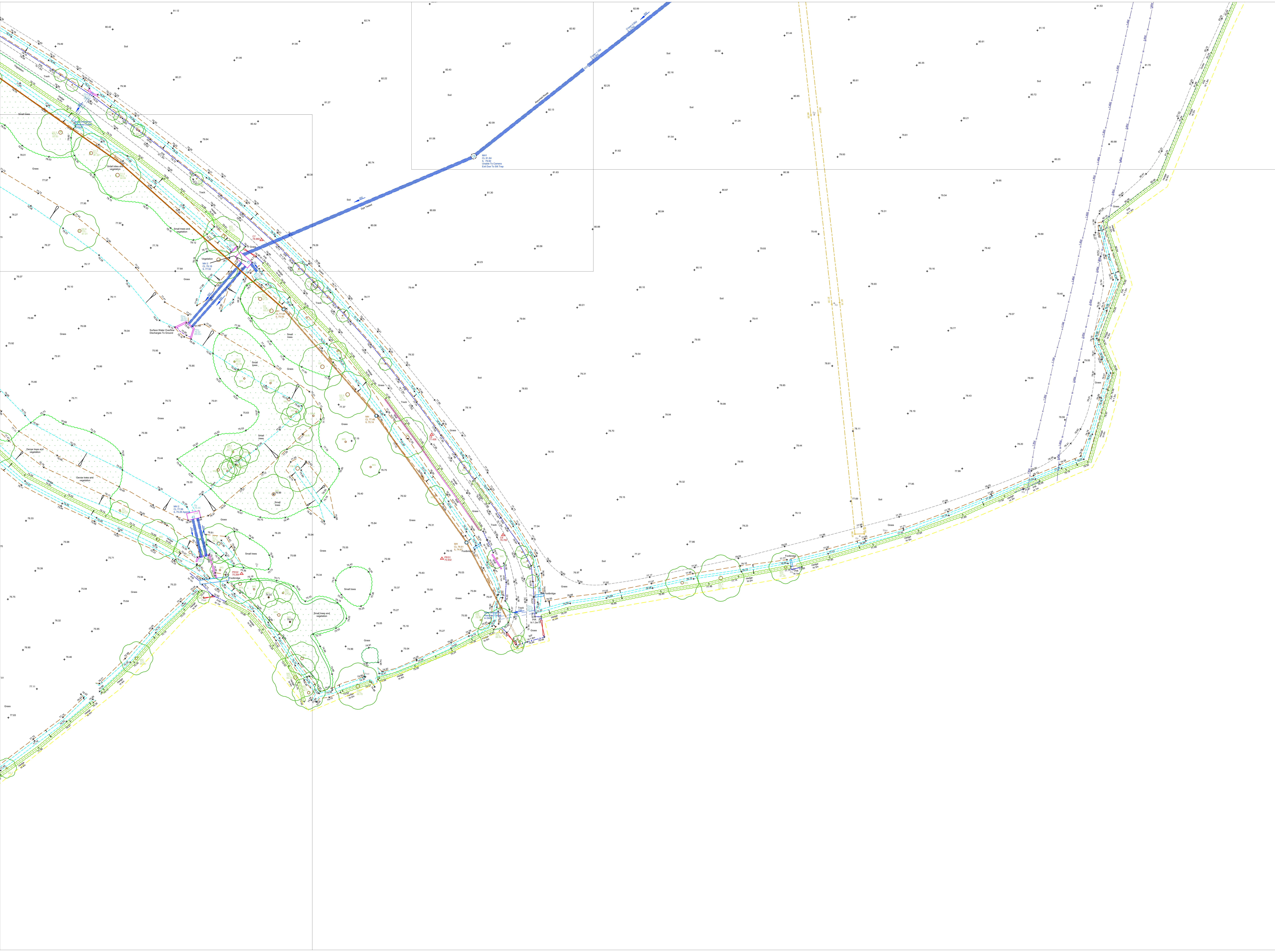
SITE LOCATION:
Sacheverell Way
Groby
Leicester

DRAWING TITLE: Utility Survey

SURVEYED BY:	DRAWN BY:	APPROVED BY:
DF	MV	RM

DRAWING NO:	SURVEY DATE:	
U24-11906	October 2024	

SCALE:	SHEET NO:	REV:
1:500 @A1	1 OF 4	



Topographical Notes

STANDARD REFERENCES

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conc	concrete	rg	road gully
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UTILITY SURVEY NOTES

AMBER UTILITIES LTD

CLIENT: Bloor Homes		
SITE LOCATION: Sacheverell Way, Groby, Leicester		
DRAWING TITLE: Utility Survey		
SURVEYED BY: DF	DRAWN BY: MV	APPROVED BY: RM
DRAWING NO: U24–11906	SURVEY DATE: October 2024	
SCALE: 1:500 @A1	SHEET NO: 2 OF 4	REV:

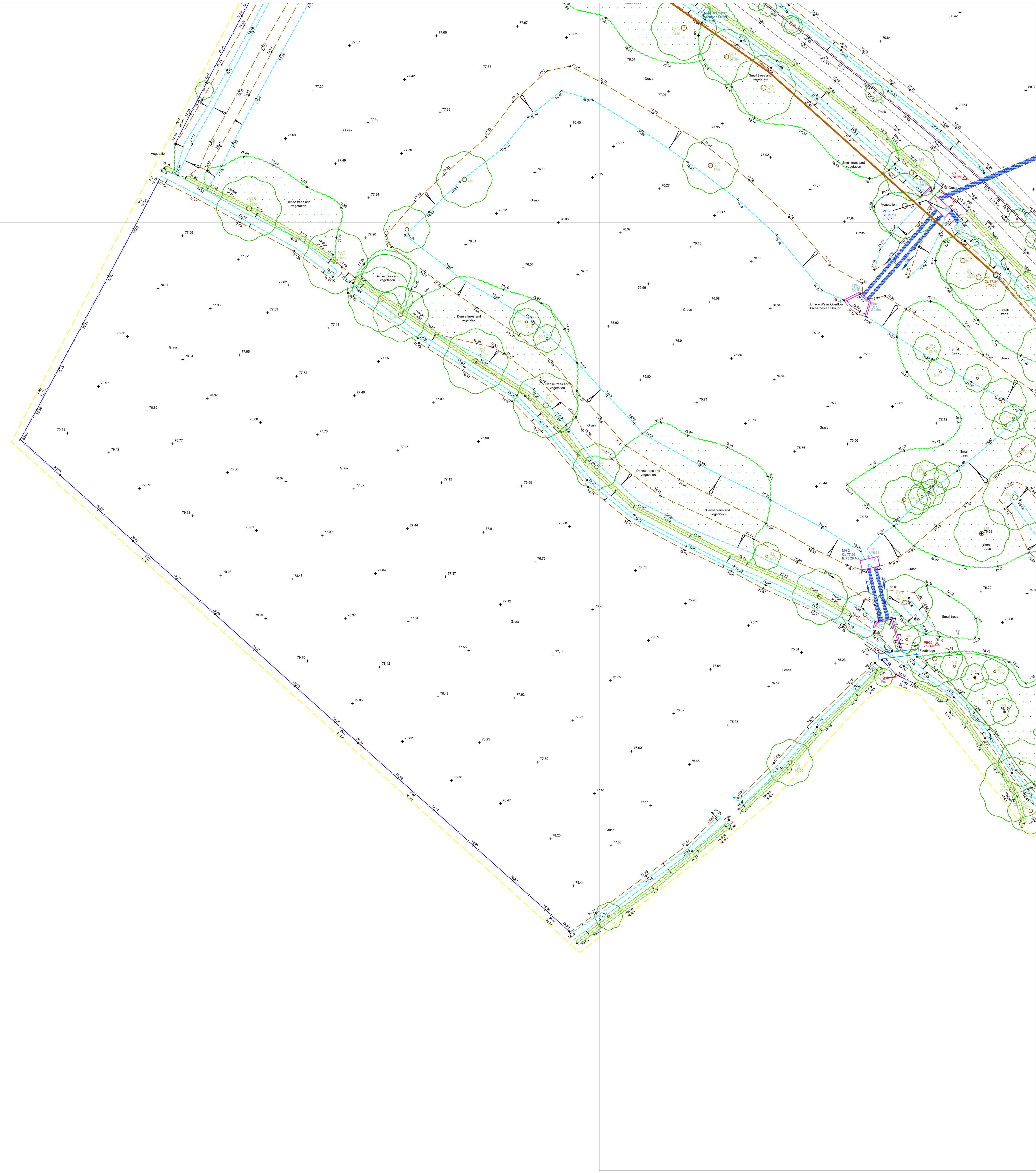
AMBER UTILITIES LTD

CLIENT: Bloor Homes

SITE LOCATION: Sacheverell Way
Groby
Leicester

DRAWING TITLE: Utility Survey

SURVEYED BY:	DRAWN BY:	APPROVED BY:
DF	MV	RM
DRAWING NO: U24-11906	SURVEY DATE: October 2024	
SCALE: 1:500 @A1	SHEET NO: 4 OF 4	REV:



Topographical Notes

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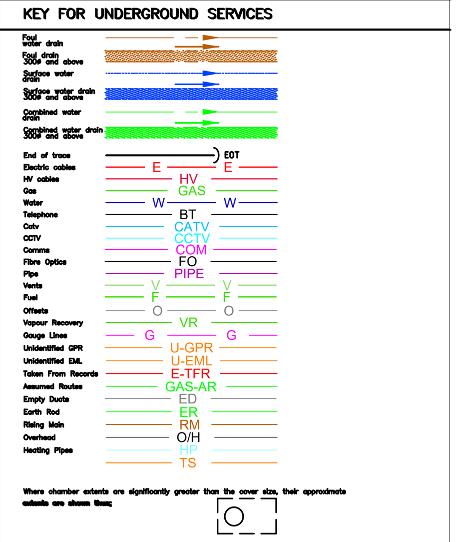
KEY FOR UNDERGROUND SERVICES



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DF	MV	RM
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SCALE: 1:500 @A1	SHEET NO: 3 OF 4	REV:

Topographical Notes

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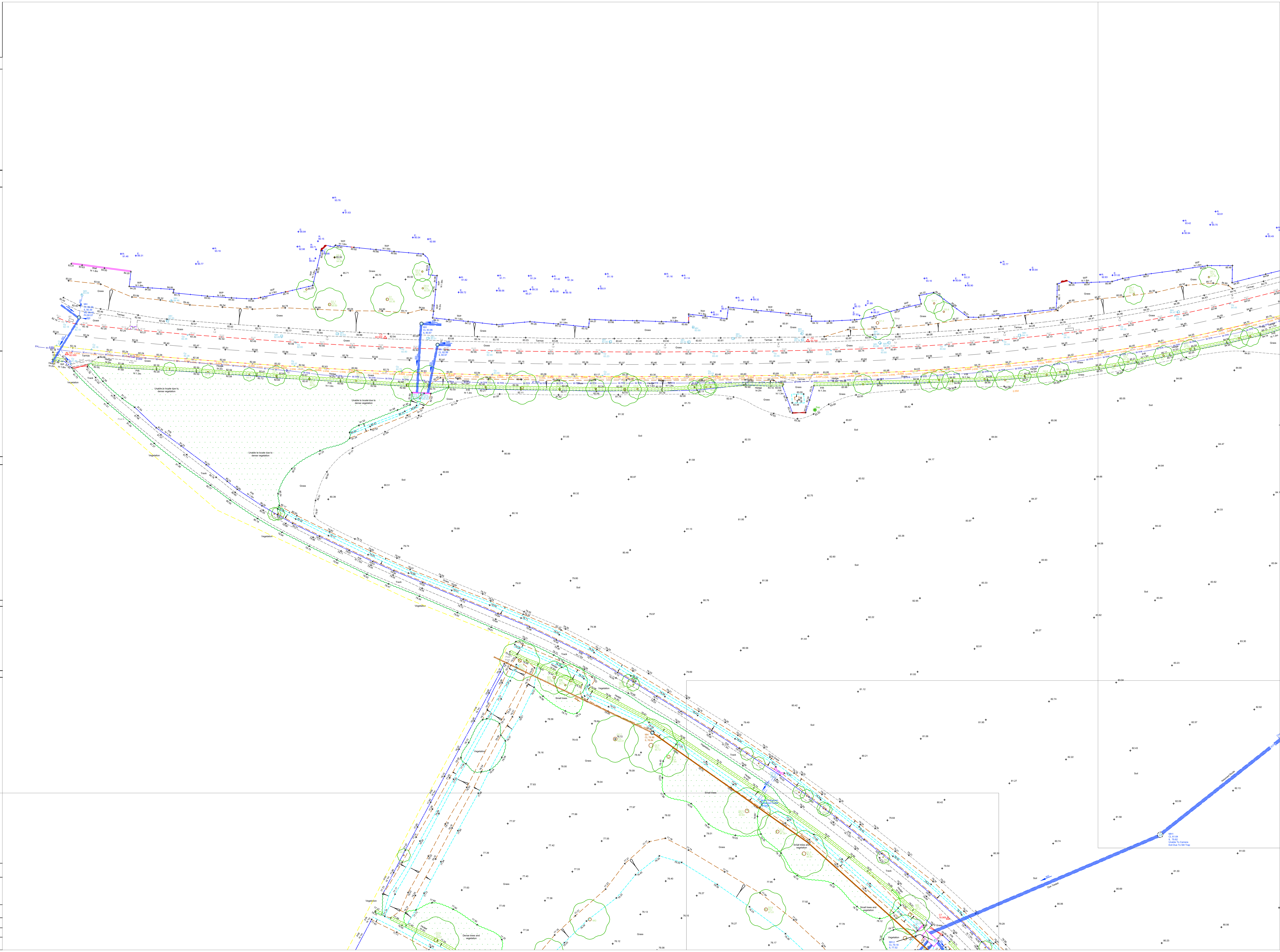

AMBER UTILITIES LTD

CLIENT:	Bloor Homes
SITE LOCATION:	Sacheverell Way Groby Leicester
DRAWING TITLE:	Utility Survey

SURVEYED BY: DF	DRAWN BY: MV	APPROVED BY: RM
DRAWING NO: U24-11906	SURVEY DATE: October 2024	
SCALE: 1:500 @A1	SHEET NO: 4 OF 4	REV:

B Topographic Survey

B.1 Topographic Survey drawing

urban contours

LEGEND -

Buildings	Overhead Cable
Wall	Concrete edge
Kerb line	Tarmac edge
Line marking	Grass verge
Drop kerb	Canopy/Overhang
Centre line	Verge
Top of bank	Bottom of bank
△	Station and Name
R:	Ridge Level
E:	Eaves Level
F:	Flat Roof Level
	Gate
I\R	Iron Railings
W\M	Wire Mesh
P\R	Post & Rail
P\W	Post & Wire
C\L	Chain Link
W\P	Wooden Panels
C\B	Close Boarded
S\P	Steel Palisade

IC	Inspection chamber	Bo	Bollard
PInv	Pipe invert	IB	Illuminated bollard
Gy	Gully	Bin	Rubbish bin
Bg	Back gully	Vp	Vent pipe
Dp	Down pipe	Grl	Ground light
Pipe	Pipe above ground	Lbox	Letter box
MH	Manhole	Stmp	Tree Stump
WL	Water level	Sty	Stile
Fl	Flood light	IFL	Internal floor level
Lp	Lamp post	THL	Threshold level
Tp	Telegraph post	Sp	Sign post
Ep	Electricity post	TH	Trialhole
Tl	Traffic light	BH	Borehole
Bus	Bus stop	ELC	Electric
Sv	Stop valve	BT	British Telecom
St	Stop tap	C'box	Control box
Er	Earth rod	TT	Tactile
Wm	Water meter	BP	Brick paved
Gas	Gas valve	CPS	Concrete paving slabs
Av	Air valve	CVR	Cover
ICU	Unidentified inspection	R/wall	Retaining wall
Wo	Wash out	TWL	Top of Wall Level
Re	Rodding eye	TCL	Tree canopy level
BB	Belisha beacon	G:	Girth
CTV	Cable tv	MG	Multi girth
Mkr	Marker post	IC	Inspection chamber
Gmkr	Gas marker post	CL:	Cover level
So	Soffit	IL:	Invert level
Fh	Fire hydrant	UTL	Unable to lift

Station Information:

Station	Easting	Northing	Height
C1	452831.001	306538.519	89.546
C2	452725.937	306491.237	85.835
C3	452607.743	306436.487	84.787
C4	452458.287	306427.535	83.790
C5	452331.286	306428.479	82.909
C6	452235.678	306423.566	82.095
C7	452500.364	306253.990	78.969
C8	452551.513	306195.515	77.426
C9	452572.943	306165.358	76.760

Rev	Date	Description	Drawn

PROJECT

Bloor Homes
Sacheverell Way
Groby

TITLE

Topographical Survey
2d

SCALE	DATE	DRAWN	CHECKED BY
1:nts@a1	19.07.20	GY	RH

Level datum	G.P.S OSGB36/15
Job number	

Drawing No.	Rev.
GROBY 001	0

Notes:

This plan has been surveyed to the scale shown.
Caution should be exercised when enlargements are made.

All critical dimensions should be confirmed on site prior to the commencement of any works.

All dimensions have been measured or estimated from ground level.

Tree species shown should be treated with caution and expert identification is advised.

Pipe sizes are estimated from a surface inspection only, Due to Health and Safety requirements.

Every effort is made to identify all visible above ground features, however it should be bourne in mind that there may be items obscured at the time of the survey.

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B.2 Topographic Survey data

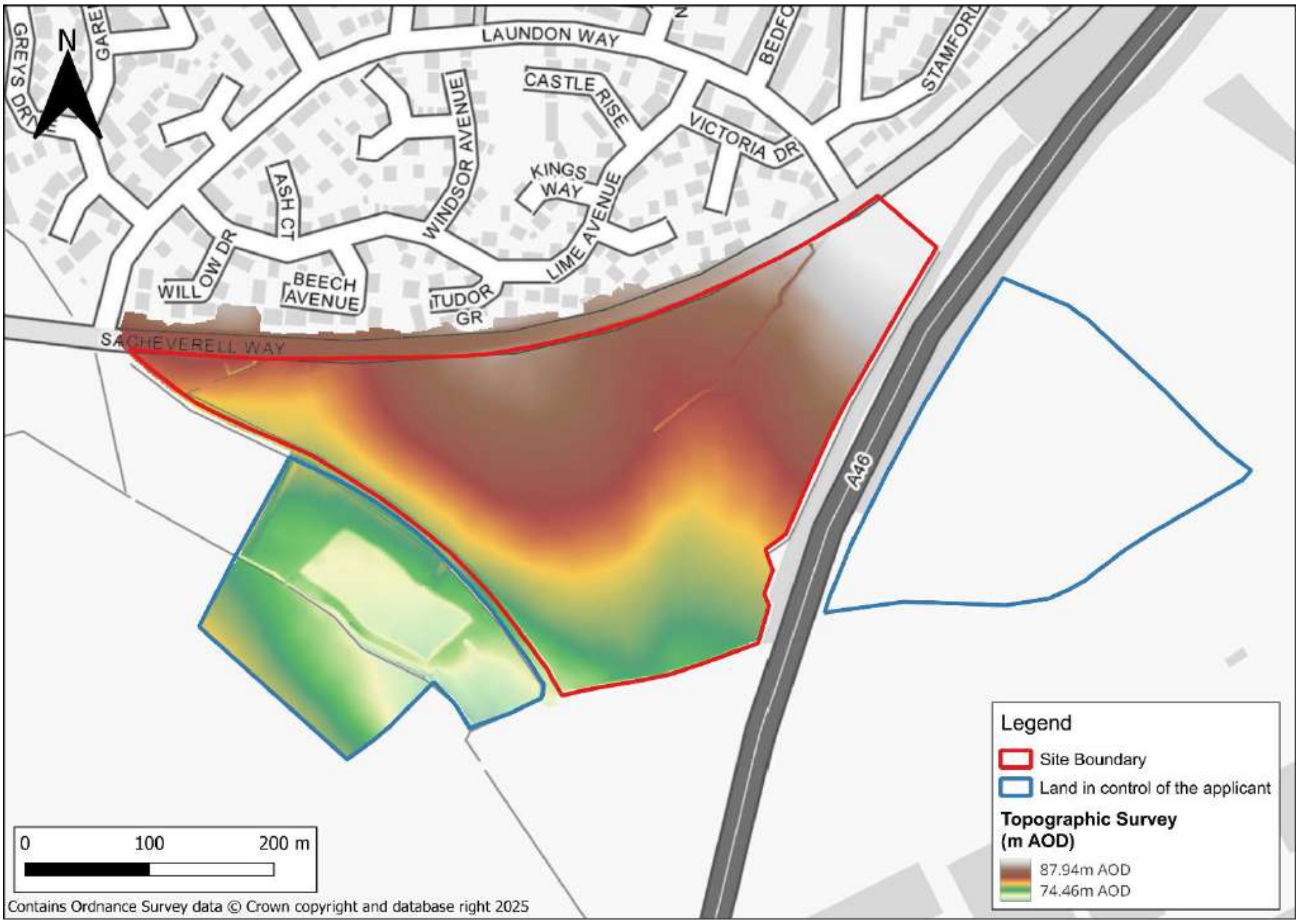

Figure B-1: Topographic Survey

B.3 Quality assessment

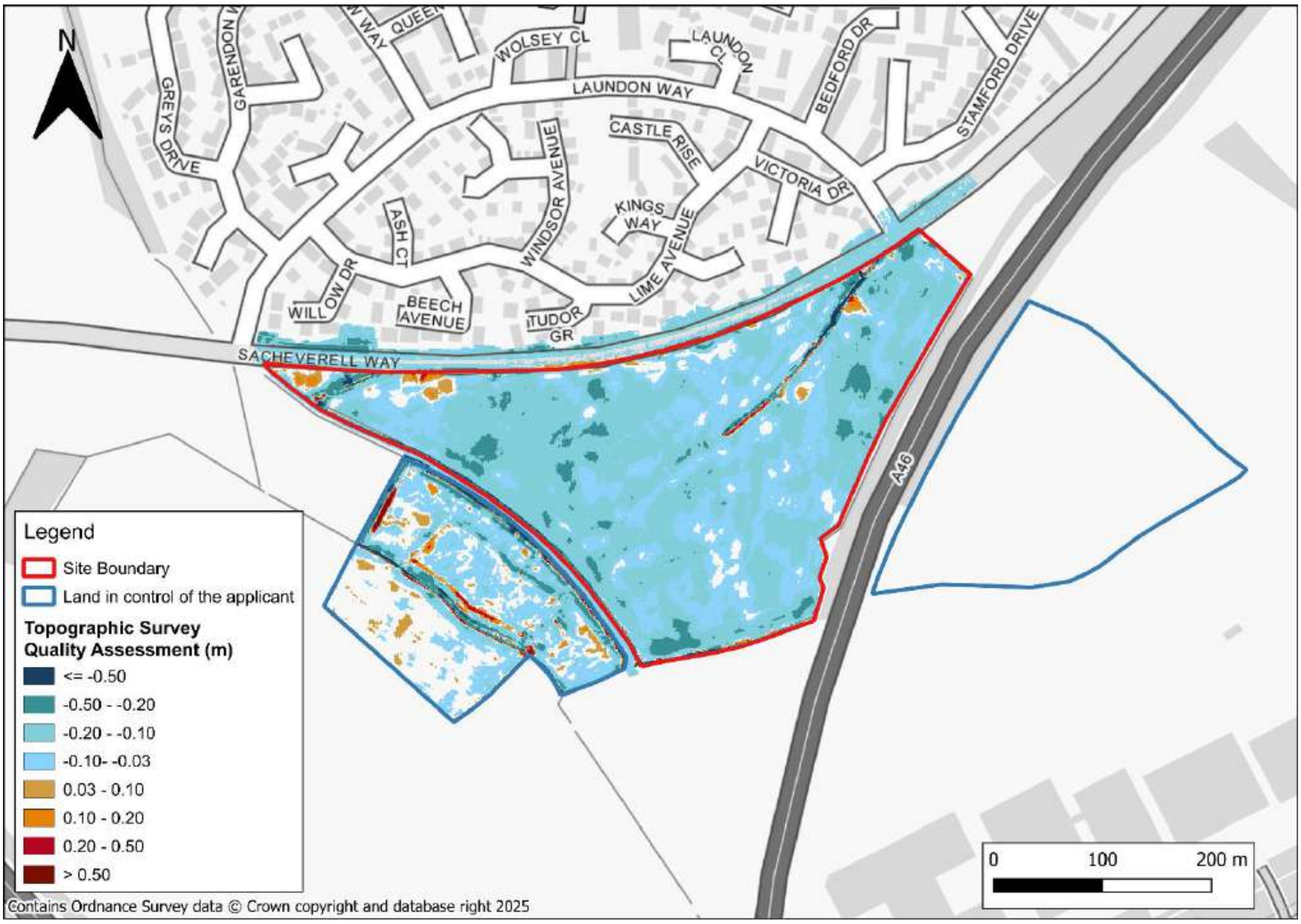

Figure B-2: Topographic Survey Quality Assessment

C Severn Trent Water sewer maps

(c) Crown copyright and database rights 2020 Ordnance Survey 100031673 | Date: 11/12/20 | Scale: 1:1250 | Map Centre: 452619,306342 | Data updated: 14/11/20 | Our Ref: 467208 - 5 | Wastewater Plan A1

Do not scale off this Map. This plan and any information supplied with it is furnished as a general guide, is only valid at the date of issue and no warranty as to its correctness is given or implied. In particular this plan and any information shown on it must not be relied upon in the event of any development or works (including but not limited to excavations) in the vicinity of SEVERN TRENT WATER assets or for the purposes of determining the suitability of a point of connection to the sewerage or distribution systems. On 1 October 2011 most private sewers and private lateral drains in Severn Trent Water's sewerage area, which were connected to a public sewer as at 1 July 2011, Transferred to the ownership of Severn Trent Water and became public sewers and public lateral drains. A further transfer takes place on 1 October 2012. Private pumping stations, which form part of these sewers or lateral drains, will transfer to ownership of Severn Trent Water on or before 1 October 2016. Severn Trent Water does not ossess complete records of these assets. These assets may not be displayed on the map. Reproduction by permission of Ordnance Survey on behalf of HMSO. © Crown Copyright and database right 2004. All rights reserved. Ordnance Survey licence number: 100031673. Document users other than SEVERN TRENT WATER business users are advised that this document is provided for reference purpose only and is subject to copyright, therefore, no further copies should be made from it.

dan.southall@bloorhomes.com

Groby Sacheverell wa

SEVERN
TRENT

GENERAL CONDITIONS AND PRECAUTIONS TO BE TAKEN WHEN CARRYING OUT WORK ADJACENT TO SEVERN TRENT WATER'S APPARATUS

Please ensure that a copy of these conditions is passed to your representative and/or your contractor on site. If any damage is caused to Severn Trent Water Limited (STW) apparatus (defined below), the person, contractor or subcontractor responsible must inform STW immediately on:
0800 783 4444 (24 hours)

a) These general conditions and precautions apply to the public sewerage, water distribution and cables in ducts including (but not limited to) sewers which are the subject of an Agreement under Section 104 of the Water Industry Act 1991(a legal agreement between a developer and STW, where a developer agrees to build sewers to an agreed standard, which STW will then adopt); mains installed in accordance with an agreement for the self-construction of water mains entered into with STW and the assets described at condition b) of these general conditions and precautions. Such apparatus is referred to as "STW Apparatus" in these general conditions and precautions.

b) Please be aware that due to The Private Sewers Transfer Regulations June 2011, the number of public sewers has increased, but many of these are not shown on the public sewer record. However, some idea of their positions may be obtained from the position of inspection covers and their existence must be anticipated.

c) On request, STW will issue a copy of the plan showing the approximate locations of STW Apparatus although in certain instances a charge will be made. The position of private drains, private sewers and water service pipes to properties are not normally shown but their presence must be anticipated. This plan and the information supplied with it is furnished as a general guide only and STW does not guarantee its accuracy.

d) STW does not update these plans on a regular basis. Therefore the position and depth of STW Apparatus may change and this plan is issued subject to any such change. Before any works are carried out, you should confirm whether any changes to the plan have been made since it was issued.

e) The plan must not be relied upon in the event of excavations or other works in the vicinity of STW Apparatus. It is your responsibility to ascertain the precise location of any STW Apparatus prior to undertaking any development or other works (including but not limited to excavations).

f) No person or company shall be relieved from liability for loss and/or damage caused to STW Apparatus by reason of the actual position and/or depths of STW Apparatus being different from those shown on the plan.

In order to achieve safe working conditions adjacent to any STW Apparatus the following should be observed:

1. All STW Apparatus should be located by hand digging prior to the use of mechanical excavators.

2. All information set out in any plans received from us, or given by our staff at the site of the works, about the position and depth of the mains, is approximate. Every possible precaution should be taken to avoid damage to STW Apparatus. You or your contractor must ensure the safety of STW Apparatus and will be responsible for the cost of repairing any loss and/or damage caused (including without limitation replacement parts).

3. Water mains are normally laid at a depth of 900mm. No records are kept of customer service pipes which are normally laid at a depth of 750mm; but some idea of their positions may be obtained from the position of stop tap covers and their existence must be anticipated.

4. During construction work, where heavy plant will cross the line of STW Apparatus, specific crossing points must be agreed with STW and suitably reinforced where required. These crossing points should be clearly marked and crossing of the line of STW Apparatus at other locations must be prevented.

5. Where it is proposed to carry out piling or boring within 20 metres of any STW Apparatus, STW should be consulted to enable any affected STW Apparatus to be surveyed prior to the works commencing.

6. Where excavation of trenches adjacent to any STW Apparatus affects its support, the STW Apparatus must be supported to the satisfaction of STW. Water mains and some sewers are pressurised and can fail if excavation removes support to thrust blocks to bends and other fittings.

7. Where a trench is excavated crossing or parallel to the line of any STW Apparatus, the backfill should be adequately compacted to prevent any settlement which could subsequently cause damage to the STW Apparatus. In special cases, it may be necessary to provide permanent support to STW Apparatus which has been exposed over a length of the excavation before backfilling and reinstatement is carried out. There should be no concrete backfill in contact with the STW Apparatus.

8. No other apparatus should be laid along the line of STW Apparatus irrespective of clearance. Above ground apparatus must not be located within a minimum of 3 metres either side of the centre line of STW Apparatus for smaller sized pipes and 6 metres either side for larger sized pipes without prior approval. No manhole or chamber shall be built over or around any STW Apparatus.

9. A minimum radial clearance of 300 millimetres should be allowed between any plant or equipment being installed and existing STW Apparatus. We reserve the right to increase this distance where strategic assets are affected.

10. Where any STW Apparatus coated with a special wrapping is damaged, even to a minor extent, STW must be notified and the trench left open until the damage has been inspected and the necessary repairs have been carried out. In the case of any material damage to any STW Apparatus causing leakage, weakening of the mechanical strength of the pipe or corrosion-protection damage, the necessary remedial work will be recharged to you.

11. It may be necessary to adjust the finished level of any surface boxes which may fall within your proposed construction. Please ensure that these are not damaged, buried or otherwise rendered inaccessible as a result of the works and that all stop taps, valves, hydrants, etc. remain accessible and operable. Minor reduction in existing levels may result in conflict with STW Apparatus such as valve spindles or tops of hydrants housed under the surface boxes. Checks should be made during site investigations to ascertain the level of such STW Apparatus in order to determine any necessary alterations in advance of the works.

12. With regard to any proposed resurfacing works, you are required to contact STW on the number given above to arrange a site inspection to establish the condition of any STW Apparatus in the nature of surface boxes or manhole covers and frames affected by the works. STW will then advise on any measures to be taken, in the event of this a proportionate charge will be made.

13. You are advised that STW will not agree to either the erection of posts, directly over or within 1.0 metre of valves and hydrants,

14. No explosives are to be used in the vicinity of any STW Apparatus without prior consultation with STW.

TREE PLANTING RESTRICTIONS

There are many problems with the location of trees adjacent to sewers, water mains and other STW Apparatus and these can lead to the loss of trees and hence amenity to the area which many people may have become used to. It is best if the problem is not created in the first place. Set out below are the recommendations for tree planting in close proximity to public sewers, water mains and other STW Apparatus.

15. Please ensure that, in relation to STW Apparatus, the mature root systems and canopies of any tree planted do not and will not encroach within the recommended distances specified in the notes below.

16. Both Poplar and Willow trees have extensive root systems and should not be planted within 12 metres of a sewer, water main or other STW Apparatus.

17. The following trees and those of similar size, be they deciduous or evergreen, should not be planted within 6 metres of a sewer, water main or other STW Apparatus. E.g. Ash, Beech, Birch, most Conifers, Elm, Horse Chestnut, Lime, Oak, Sycamore, Apple and Pear. Asset Protection Statements Updated May 2014

18. STW personnel require a clear path to conduct surveys etc. No shrubs or bushes should be planted within 2 metre of the centre line of a sewer, water main or other STW Apparatus.

19. In certain circumstances, both STW and landowners may wish to plant shrubs/bushes in close proximity to a sewer, water main of other STW Apparatus for screening purposes. The following are shallow rooting and are suitable for this purpose: Blackthorn, Broom, Cotoneaster, Elder, Hazel, Laurel, Privet, Quickthorn, Snowberry, and most ornamental flowering shrubs.

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
	F		0	0
1401	F	82.86	81.3	1.56
1403	F	82.12	80.81	1.31
1501	F	84.41	82.34	2.07
1504	F	83.58	81.8	1.78
1506	F	83.29	81.37	1.92
1602	F	85.3	83.64	1.66
1603	F	85.44	83.85	1.59
2301	F	80.94	78.26	2.68
2401	F	82.11	79.37	2.74
2403	F	82.34	80.53	1.81
2407	F	84.64	82.06	2.58
2408	F	85.54	83.52	2.02
2412	F	82.46	79.75	2.71
2415	F	81.5	79.18	2.32
2501	F	86.47	83.83	2.64
2504	F	85.19	82.8	2.39
2506	F	85.53	83.28	2.25
2601	F	88.86	86.93	1.93
2608	F	87.57	85.76	1.81
3301	F	79.68	77.3	2.38
3402	F	84.99	82.92	2.07
3403	F	82.97	80.43	2.54
3408	F	83.35	81.13	2.22
3411	F	82.77	80.25	2.52
3501	F	87.83	85.83	2
3503	F	89.48	87.52	1.96
3507	F	90.45	87.85	2.6
3602	F	93.75	90.92	2.83
3603	F	93.77	90.79	2.98
3606	F	90.03	88.13	1.9
4201	F	78.54	76.17	2.37
4301	F	79.02	76.87	2.15
4400	F		0	0
4402	F	84.91	82.28	2.63
4404	F	85.85	83.96	1.89
4405	F	84.71	82.28	2.43
4409	F	83.88	81.92	1.96
4410	F	83.47	81.36	2.11
4414	F	83.7	81.69	2.01
4502	F	86.01	83.72	2.29
4503	F	86.18	84.15	2.03
4506	F	90.14	88.39	1.75
4510	F	87.12	84.8	2.32
4602	F	89.89	87.97	1.92
5101	F	76.55	74.66	1.89
5102	F	76.55	0	0
5201	F	77.84	75.67	2.17
5404	F	85.82	82.72	3.1
5406	F	85.84	82.58	3.26
5408	F	85.48	83.13	2.35
5504	F	87.21	85.11	2.1
5605	F	88.79	86.64	2.15
6001	F		0	0
6002	F	75.86	0	0
6003	F	75.86	0	0
6502	F	88.95	86.54	2.41
6504	F	88.86	86.68	2.18
6506	F	87.09	84.74	2.35
6508	F	85.94	83.5	2.44
6509	F	85.92	83.81	2.11
6511	F	87.25	84.76	2.49
6602	F	89.72	87.49	2.23
6603	F	89.29	87.54	1.75
6606	F	91.26	88.99	2.27
6611	F	90.4	88.73	1.67
7500	F		0	0
7504	F	88.59	86.12	2.47
7505	F	88.73	86.22	2.51
7508	F	88.37	86.39	1.98
7511	F	86.82	84.94	1.88
7512	F	88.82	86.63	2.19
7514	F	88.87	86.55	2.32
7601	F	89.53	87.05	2.48
7604	F	90.92	87.69	3.23
8602	F	91.48	89.11	2.37
8604	F	90.71	88.85	1.86
8607	F	90.28	88.12	2.16
8609	F	90.96	89.04	1.92
8611	F	89.74	86.87	2.87
1402	S	83.15	81.69	1.46
1404	S	82.81	81.14	1.67
1405	S	82.62	80.88	1.74
1406	S	84.72	82.87	1.85
1407	S	80.42	78.6	1.82
1502	S	84.43	82.9	1.53
1503	S	83.77	82.38	1.39
1505	S	85.14	83.33	1.81
1601	S	85.33	84.01	1.32
1604	S	85.5	84.24	1.26
2402	S	82.26	80.41	1.85
2404	S	82.25	80.95	1.3

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert
2406	S	84.46	82.38	2.08
2409	S	85.53	83.82	1.71
2410	S	82.56	81.28	1.28
2411	S	82.84	81.19	1.65
2413	S	84.42	81.44	2.98
2502	S	86.64	84.34	2.3
2503	S	85.29	83.42	1.87
2505	S	85.65	83.76	1.89
2507	S	89.22	87.11	2.11
2602	S	88.77	87.43	1.34
2607	S	87.58	86.36	1.22
3401	S	84.96	83.08	1.88
3404	S	82.93	80.95	1.98
3406	S	83.96	80.77	3.19
3409	S	82.58	81.09	1.49
3410	S	86.25	84.75	1.5
3502	S	87.87	86.33	1.54
3504	S	89.54	88.05	1.49
3505	S	91.23	89.71	1.52
3506	S	90.41	88.2	2.21
3508	S	90.47	88.57	1.9
3601	S	93.71	91.17	2.54
3604	S	93.79	91.09	2.7
3605	S	90	88.65	1.35
4401	S	85.06	82.46	2.6
4403	S	85.88	84.37	1.51
4406	S	84.69	82.6	2.09
4407	S	83.87	81.94	1.93
4408	S	83.84	81.89	1.95
4411	S	83.67	82.02	1.65
4412	S	83.47	81.59	1.88
4413	S	83.6	82.4	1.2
4415	S	83.75	82.7	1.05
4501	S	86.03	84.05	1.98
4504	S	86.18	84.53	1.65
4507	S	90.13	88.66	1.47
4508	S	86.85	85.46	1.39
4509	S	87.13	85.21	1.92
4601	S	90.42	88.87	1.55
4606	S	89.85	88.23	1.62
5401	S	84.1	82.47	1.63
5402	S	84.42	82.78	1.64
5403	S	85.81	83.24	2.57
5405	S	85.85	82.99	2.86
5407	S	85.43	83.59	1.84
5409	S	85.71	83.64	2.07
5501	S	87.01	85.04	1.97
5502	S	86.66	85.36	1.3
5503	S	85.93	83.78	2.15
5508	S	87.17	85.73	1.44
5604	S	88.81	87.11	1.7
6401	S	84.99	83.31	1.68
6501	S	88.93	86.89	2.04
6503	S	88.99	87.13	1.86
6505	S	86.97	84.23	2.74
6507	S	85.87	83.9	1.97
6510	S	85.85	84.17	1.68
6512	S	87.08	85.11	1.97
6601	S	89.68	87.96	1.72
6604	S	89.32	87.8	1.52
6605	S	91.17	88.14	3.03
7401	S	85.93	84.01	1.92
7501	S	87.62	86.04	1.58
7503	S	88.97	86.96	2.01
7506	S	88.97	87.66	1.31
7507	S	88.43	87.21	1.22
7509	S	87.4	85.7	1.7
7510	S	86.91	85.23	1.68
7513	S	88.84	86.92	1.92
7602	S	89.6	87.56	2.04
7603	S	90.73	88.8	1.93
8501	S	88.79	86.28	2.51
8502	S	89.07	86.49	2.58
8503	S	88.91	86.63	2.28
8504	S	91.13	89.69	1.44
8603	S	90.72	87.53	3.19
8605	S	90.37	87.37	3
8608	S	90.62	88.94	1.68
8610	S	91.39	89.89	1.5
8612	S	89.78	87.27	2.51
8613	S	91.49	88.15	3.34
9601	S	92.33	90.9	1.43

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert

2405	S	82.97	80.61	2.36

D Sensitivity Analysis

D.1 Sensitivity to roughness

Figure D-1 shows the impact on flood extents within the site when the Manning's 'n' roughness values are increased and decreased by 20%. The model results indicate a slight increase in flood extent within the site when the roughness was decreased by 20%, while a 20% increase in roughness remains the same as the baseline extent. It shows that within the development site, the model is not sensitive to roughness changes.

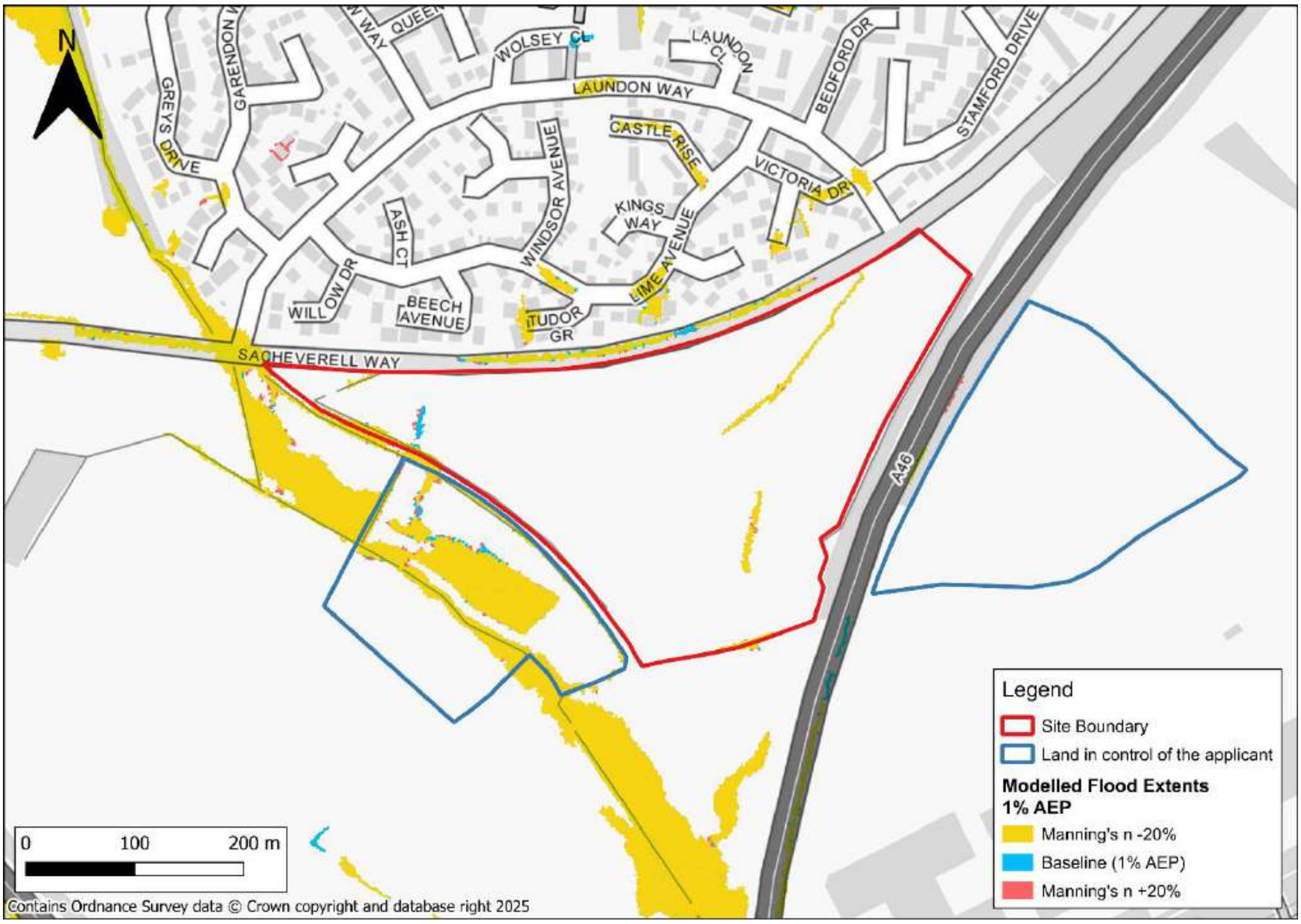

Figure D-1: Sensitivity to changes in roughness coefficients

D.2 Sensitivity to fixed runoff coefficient (FRC)

Figure D- 2 shows the impact on flood extents within the site when the fixed runoff coefficient values are increased and decreased by 20%. The model results indicate a minor increase in flood extent within the site when the fixed runoff coefficient was increased by 20%, while a 20% reduction in the fixed runoff coefficient is predicted to result in a corresponding reduction in flood extent. This suggests that the model is slightly sensitive to changes in fixed runoff coefficient values in this location.

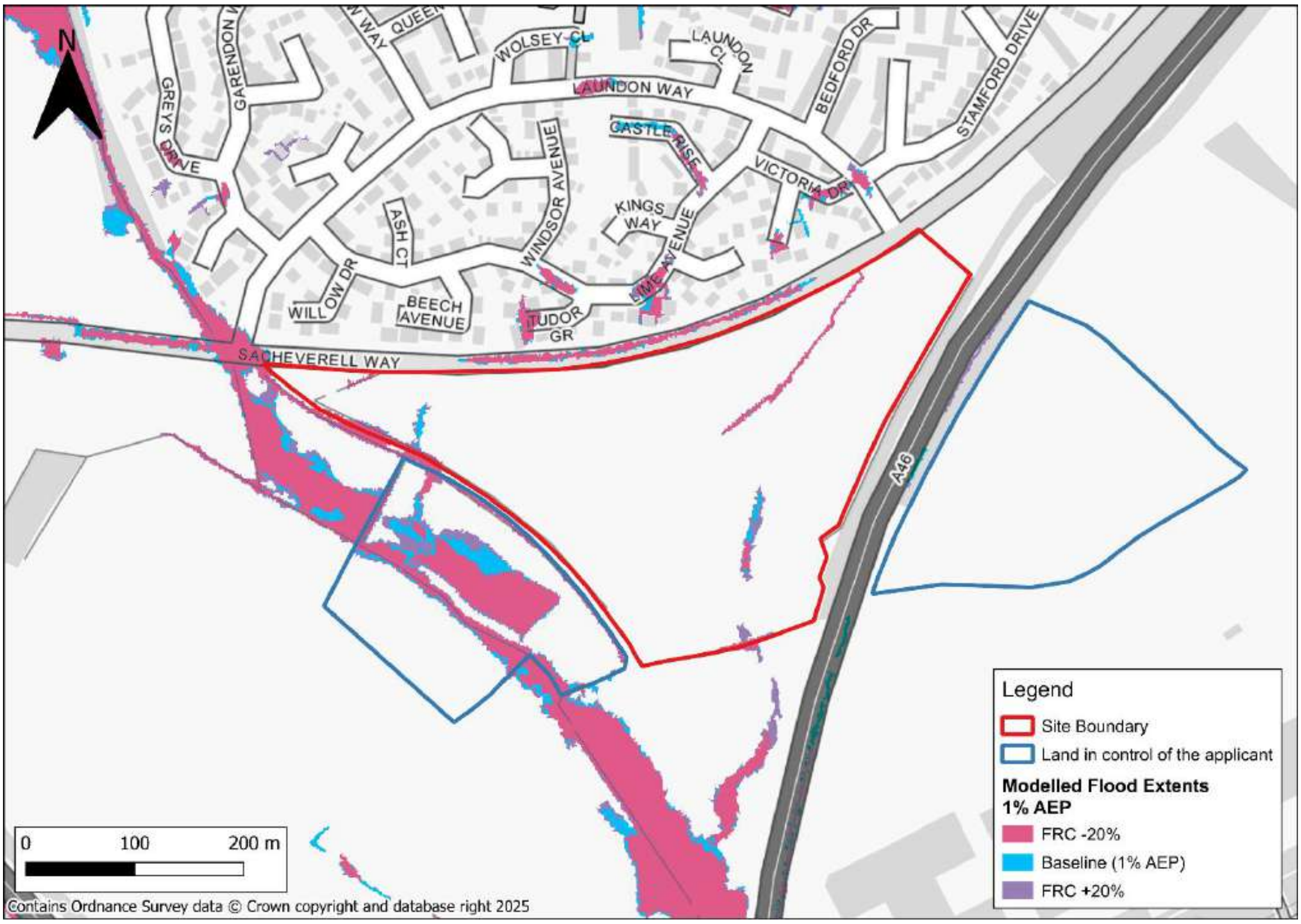

Figure D- 2: Sensitivity to changes in fixed runoff coefficient (FRC)

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