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Land South of The Forty Cricklade

Hannick Homes

Hydraulic Modelling Technical Note
June 2025





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Executive Summary

Current Environment Agency (EA) mapping indicates that the majority of Site is at a high risk of surface water flooding with depths shown to reach a maximum of 0.3m.

Surface water flooding is considered the dominant form of flood risk to the Site, and as such, Rappor Consultants Ltd have undertaken hydraulic modelling using a direct rainfall runoff model to confirm both existing risk to the Site and the risk posed by the proposed development. The modelling undertaken for the Proposed Development assesses both the onsite and offsite impacts such development would have on pluvial risk. Following this, mitigation measures have been included in modelling to reduce pluvial risk on site whilst also ensuring off-site increases in pluvial flooding, because of the Proposed Development, are kept to a minimum.

Baseline scenarios, inclusive of climate change, as well as sensitivity analyses were run to assess the existing pluvial risk to Site at a higher, more detailed resolution than currently available from the Environment Agency's mapping.

This modelling exercise has confirmed that the mitigation measures modelled will ensure pluvial risk on site is acceptable for the Proposed Development. It has also ensured any off-site increases to pluvial risk, as a result of the Proposed Development, is within model tolerance and deemed acceptable by the LLFA.



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1 Introduction

Background

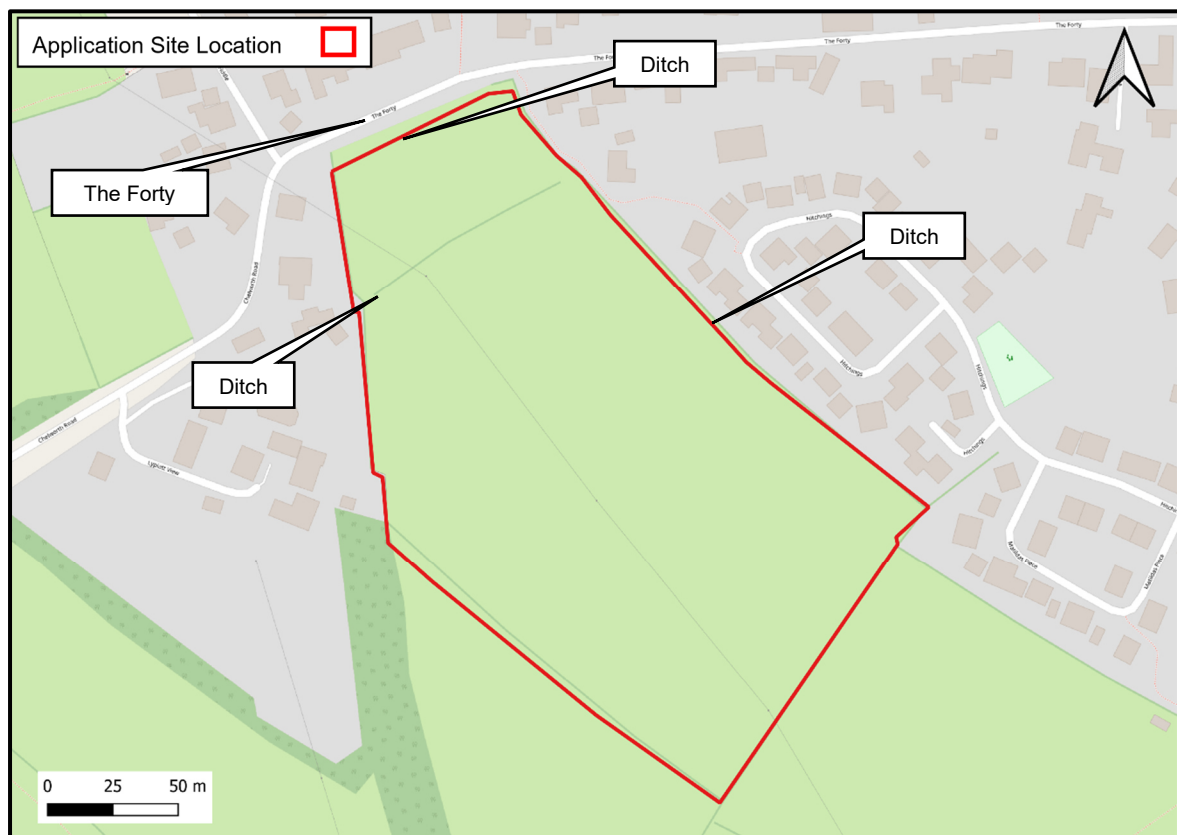
- 1.1 The purpose of this Hydraulic Modelling Technical Note is to firstly assess the current risk of surface water flooding on Site, as well as the future risk of surface water flooding, both on and off Site, as a result of the proposed development.
- 1.2 This Hydraulic Modelling Technical Note then provides details of the modelled mitigation and outlines the impact of this to flood risk on Site as well as the surrounding area.



2 Existing Site & Hydrology Characteristics

Site Location & Composition

- 2.1 The Site is located south off The Forty, located southwest of Cricklade. The approximate co-ordinates for the centre of the Site are E: 409633; N: 193035, with the nearest post code of SN6 6NJ (**Figure 2.1**).
- 2.2 The existing Site consists entirely of greenfield grazing land (**Figure 2.1**). The Forty runs parallel to the Site's northern boundary and there are residential dwellings located immediately adjacent to the Site's eastern boundary. Further dwellings are located immediately west of the Site's northwestern boundary. Land south of Site consists of greenfield arable land.



(Source: OpenStreetMaps)

Figure 2.1 Site Location

Topography

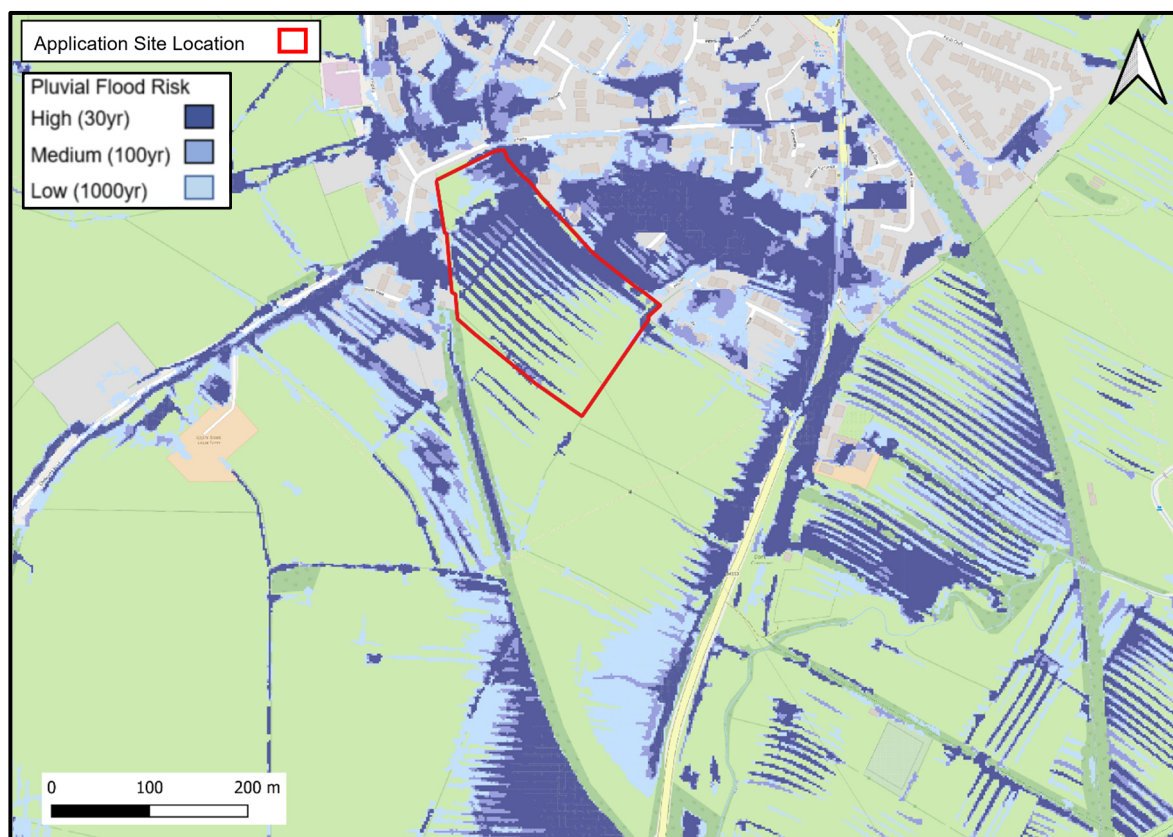
- 2.3 A topographic survey was carried out in July 2022 and shows ground levels on the Site generally falls in a south easterly direction from 81.41 metres Above Ordnance Datum (mAOD) in the northwestern corner of Site to 80.63 mAOD in the northeast of Site. The topographic survey also shows the presence of ditches down the eastern boundary as well as across northern boundary. The survey also shows a ditch that runs from west to east in the north of site. All ditches are labelled in **Figure 2.1**. A copy of the topographic survey is included in within **Appendix A**.



3 Hydrological and Hydraulic Assessment

Background

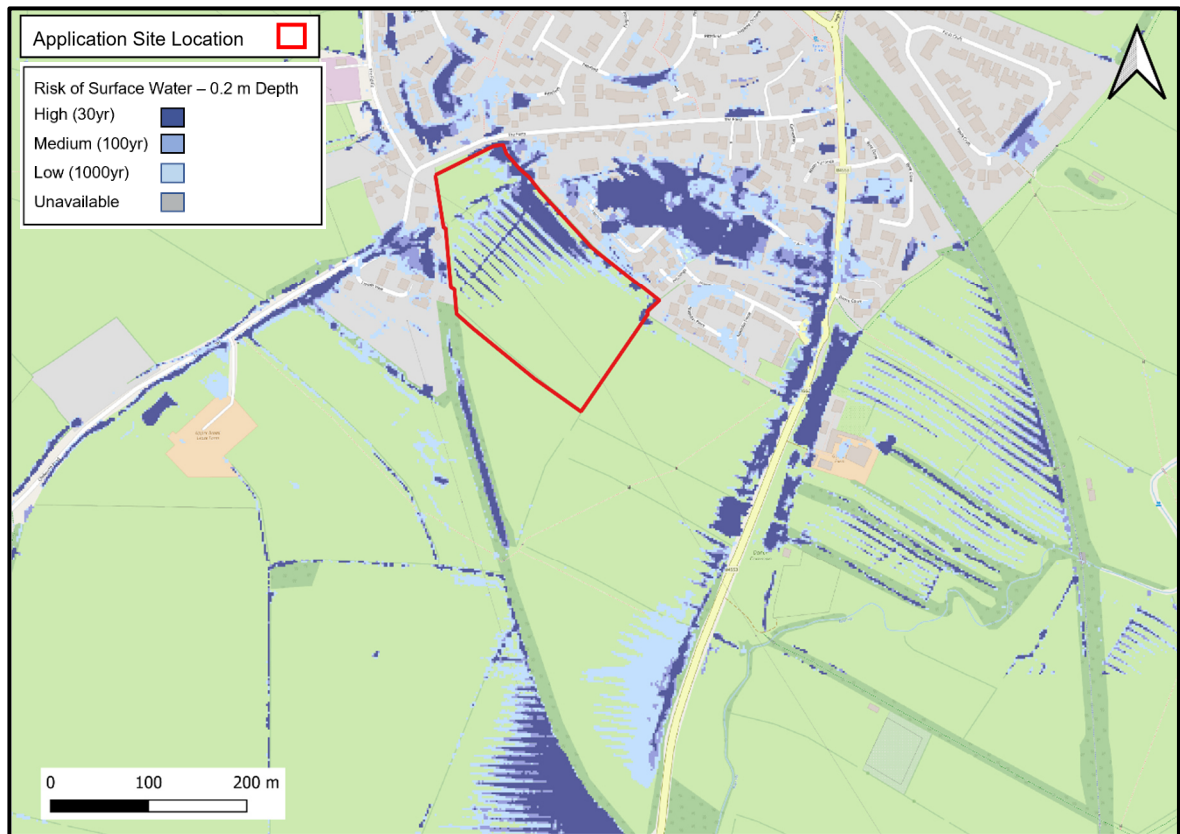
- 3.1 Pluvial flooding can occur during prolonged or intense storm events when the infiltration potential of soils, or the capacity of drainage infrastructure, is overwhelmed leading to the accumulation of surface water and the generation of overland flow routes.
- 3.2 Risk of flooding from surface water mapping has been prepared¹, and is discussed below, this mapping shows the potential flooding which could occur when rainwater does not drain into drainage systems or infiltrate into the ground but lies on or flows over the ground instead.
- 3.3 The Surface Water (Pluvial) Flood map provided by the Environment Agency (**Figure 3.1**) indicates that the majority of Site is at a high risk of surface water flooding. The majority of surface water risk on Site is modelled to have maximum depths of 0.2 m (**Figure 3.2**) with a section in the northeastern corner of Site reaching depths of up to 0.3 m (**Figure 3.3**).



(Source: OpenStreetMap/Environment Agency)

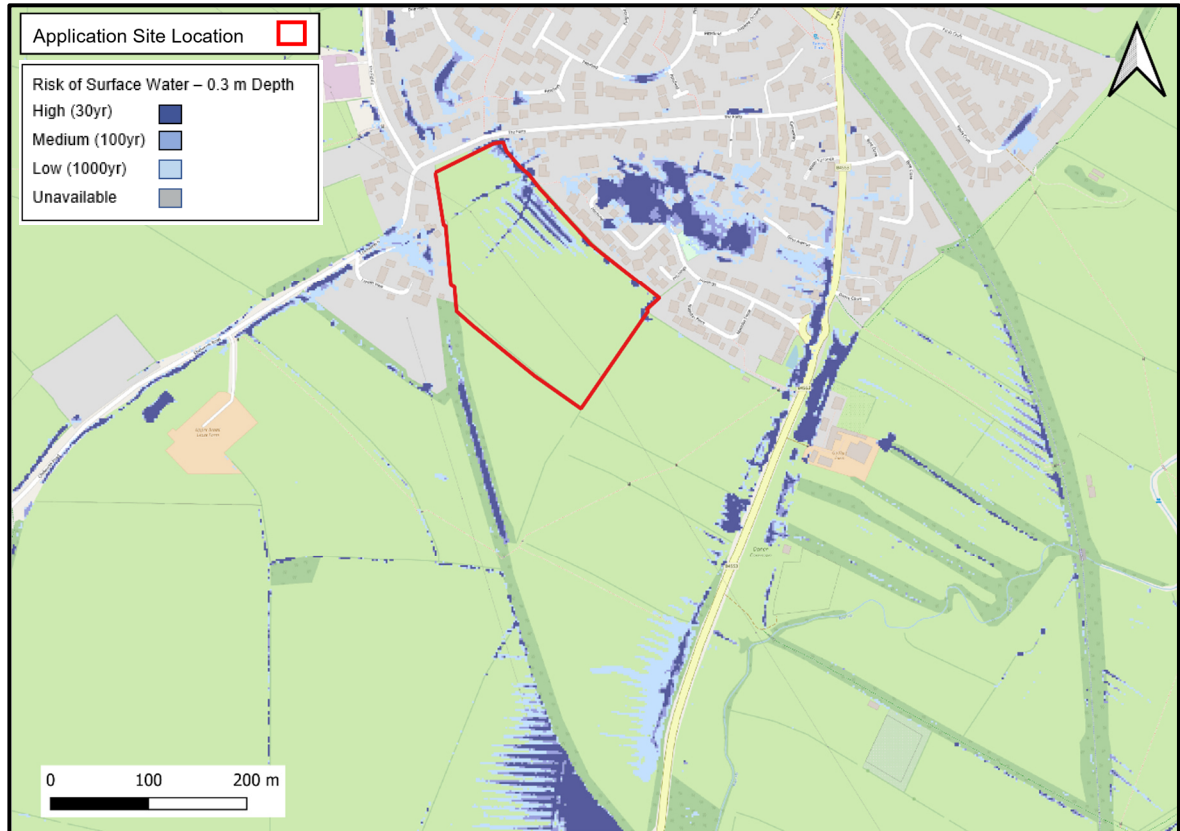
Figure 3.1 Pluvial Flood Extents

¹ <https://flood-warning-information.service.gov.uk/long-term-flood-risk/map>



(Source: OpenStreetMap/Environment Agency)

Figure 3.2 Pluvial Flood Depths – 0.2m



(Source: OpenStreetMap/Environment Agency)

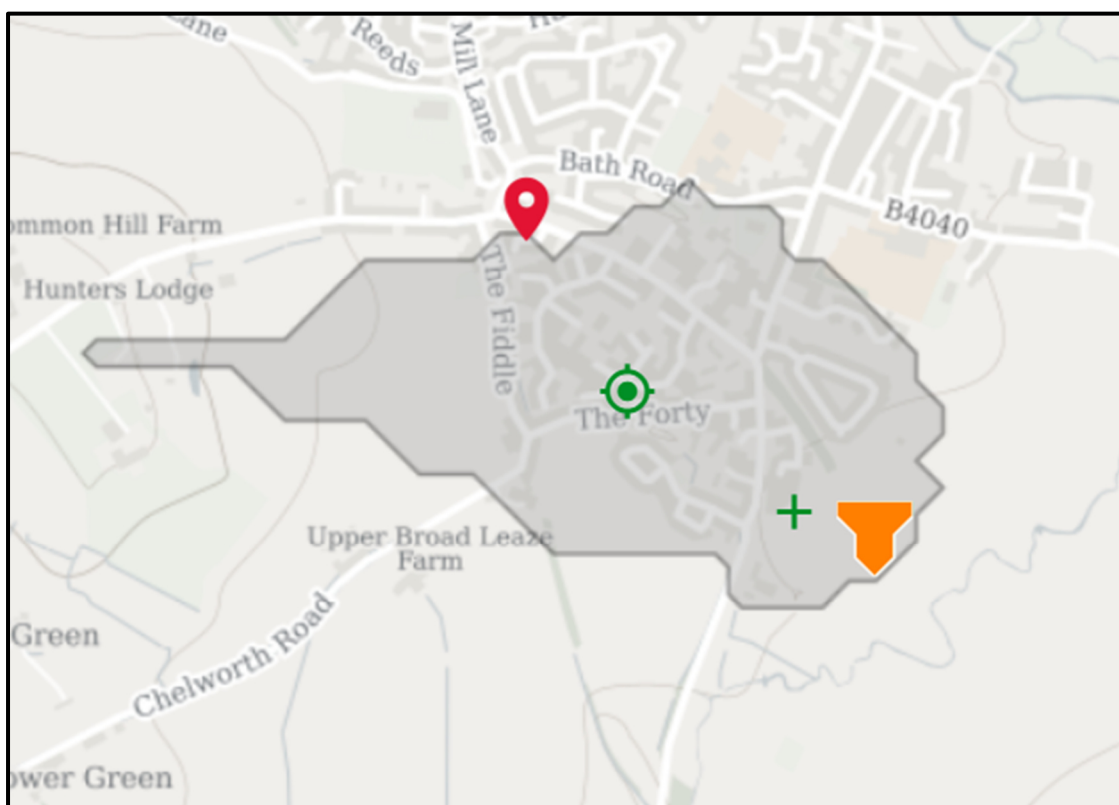
Figure 3.3 Pluvial Flood Depths – 0.3m



- 3.4 Whilst the pluvial maps give a good indication of flood risk, they do not fully take into account any underground drainage systems, nor contain any Site-specific information owing to the strategic nature of the mapping and supporting models.

Flood Catchment Boundary

- 3.5 The catchment for which the Site lies within is illustrated in **Figure 3.4**. The outflow coordinates of the catchment (410150,192900) are those used to generate the below and extends a short distance downstream of the Site so as to avoid any backwater/boundary effects and ensure any modelling is as representative as possible.



(Source: OpenStreetMap, FEH Web Service, Rappor)

Figure 3.5 Catchment Boundaries

Rainfall Modelling

Rainfall

- 3.6 Rainfall depths are generated within FEH and are derived from the catchment parameters taken from the FEH Web Service from an outlet point, grid reference 410150, 192900.
- 3.7 The 1 in 10-year, 1 in 30-year, 1 in 30-year plus 35% climate change, 1 in 100-year and 1 in 100-year plus 40% climate change, and 1 in 1,000-year storm events have been modelled to gain an understanding of the range of events and impacts these have on the Site, access routes and surrounding areas.
- 3.8 Multiple storm durations were run and assessed for the design event (100 year plus 40% climate change) and the critical storm duration was identified. This analysis concluded of



the storm durations tested (1-hour, 3-hour and 6-hour) the 6-hour storm was found to cause greatest flood depths and extents on Site – this storm duration was then taken forward as the critical storm duration and used for running the remaining return periods.

- 3.9 The 1 in 100-year plus climate change event, for which a 40% allowance is required in this catchment, is the extreme storm which new developments should be designed to withstand, whereby flooding of the network may occur but it must be safely contained away from buildings or key access/egress routes. Whilst this is the 'design event' in accordance with national policy/guidance, it is noted that the allowance for climate change assumed a design life of up to 100 years, which far exceed the likely lifetime of this development (75 years) and therefore adopts a conservative approach in assessing Site specific risk. The additional events are to gain an understanding of the more extreme events but also those more frequent to determine at which point the access and egress becomes 'at risk' as shown on the EA's mapping.
- 3.10 All the modelling undertaken follows standard (and national) modelling guidance as issued by the EA for rainfall runoff models. This includes measures such as inclusion of 'stubby' buildings to reflect the impact of buildings on flow routes and the assumption that all sewerage in the catchment is 'full' and therefore all rainfall generates overland flow.

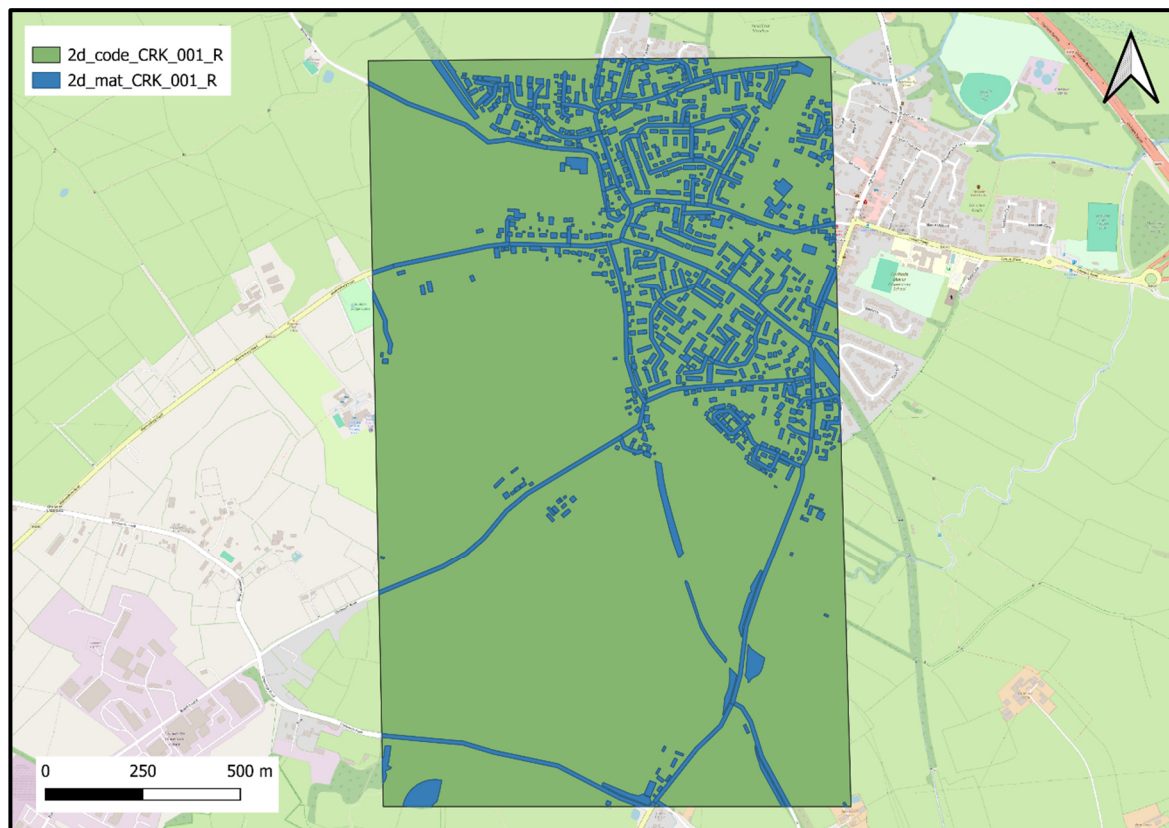
Run-off Calculation

- 3.11 Factors which can affect runoff calculations are as follows:
- a) Permeability of soils, with runoff less accurately predicted in highly permeable soils. The soils at the Site within the catchment were described on Soilscales as "Slightly acid loamy and clayey soils with impeded drainage". The entire catchment has an SPRHOST value of 49.8%, indicating average permeability in comparison to the UK as a whole.
 - b) Small drainage catchments (<5km²) can result in small rainfall depths (it should be noted the catchment used in this modelling exercise was 0.64km²). Runoff calculated by models with an initial storage component (such as the PDM model used in ReFH) may therefore be very sensitive to storage parameters and initial conditions. Total runoff estimates may therefore be uncertain.
 - c) Urbanisation resulting in different surface characteristics and runoff coefficients to the natural catchment.
- 3.12 Given the complex nature of the issues outlined above, the following method has been used to address the limitations identified above and provide a robust runoff parameterisation for modelling:
- a) Runoff calculated from 'rural' areas calculated by taking the SPRHOST value from the FEH Catchment Descriptors as a representative percentage run-off value for the Site of interest.
 - b) Runoff calculated from 'urban' areas using a hybrid approach which takes the weighted average of the rural runoff (as described above) and a 90% run-off from impermeable areas. The weighting factor is the Percentage Impermeable (PIMP) value as used in the Wallingford procedure. The revised catchment is indicated to be largely rural with a PIMP value of 0.122, the overall Percentage Runoff was calculated as 46% (0.461) across the RF boundary. The Site itself is entirely urban.
 - c) It has been assumed that for the purpose of the direct rainfall modelling that no water enters any sewer system. This is a conservative approach as this system



will help to alleviate ponding in low-lying areas. This approach is not considered to impact the predicted flow routes as all flows will be routed via the topography.

- d) The results of applying these methods are summarised in **Table 3.1** and can be viewed in **Figure 3.5**.



(Source: OpenStreetMap, FEH Web Service, Rappor)

Figure 3.6 Urban/Rural Catchment De-lineation

Method	Percentage Run-off Values
SPRHOST (from FEH Data)	49.8%
PIMP weighted rural/urban – Total	12.2%

Table 3.1 Runoff Parameterisation, Rural and Urban

Baseline Hydraulic Assessment

Model Type

- 3.13 Based on the identified requirement to consider overland flow routes, a linked 2D model has been developed using TUFLOW HPC 2025.0.3. This was run in double precision to follow standard guidance for direct run-off modelling.

Model Grid

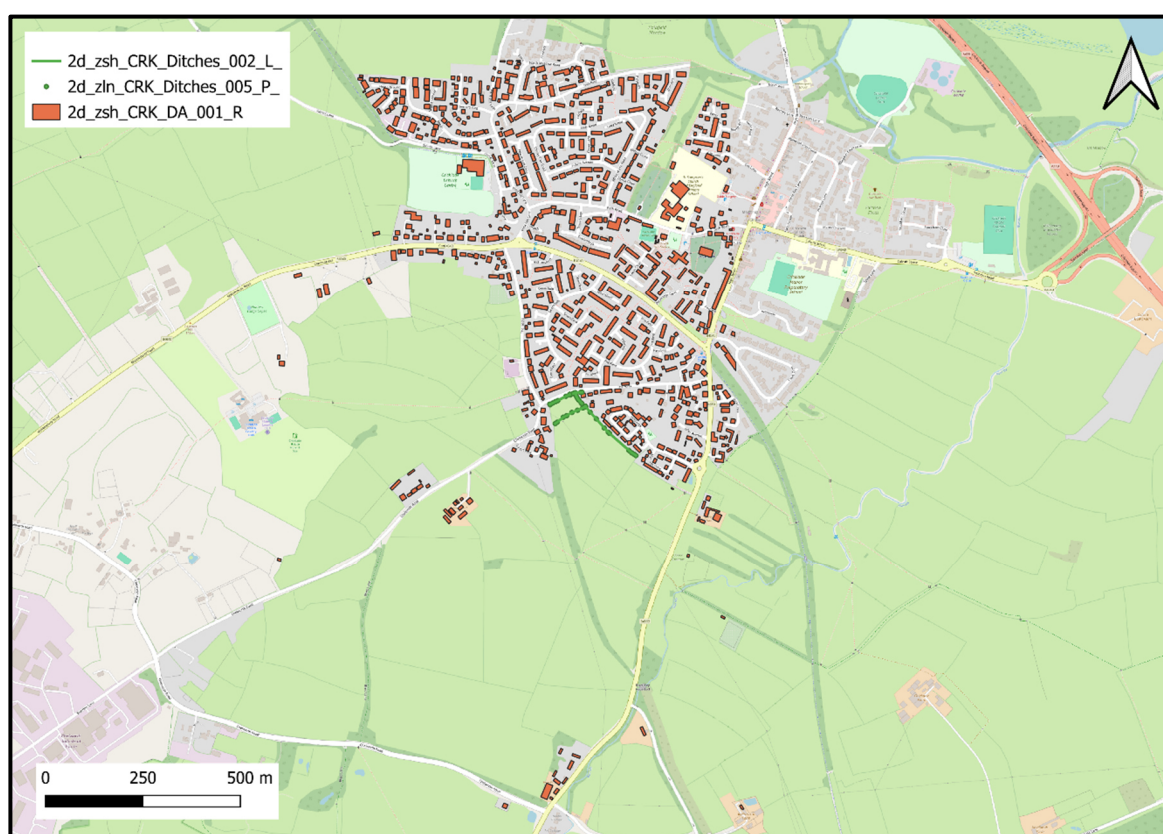
- 3.14 The 2D model is based on LiDAR data (1m resolution surveyed in 2022 and downloaded for use in April 2025) to represent ground levels for the rest of the wider catchment. The final grid file referenced by the model is 'merged_lidar.asc'. Whilst a topographic survey



was provided, this was deemed to be at a lower resolution compared to the LiDAR data, thus, use of LiDAR to define the topography for the full model domain was deemed appropriate.

DTM Adjustments

- 3.15 The DTM was adjusted to include the ditches identified from the topographic survey. Ditches were added as the '2s_zsh_CRK_Ditches_005_L_' were attached to '2s_zln_CRK_Ditches_005_P_' lowered the DTM by the points identified as the ditch on the topographic survey.
- 3.16 Furthermore, buildings (identified based on the OS Local Mapping) were added as 'stubby' (file reference: '2d_zsh_zsh_CRK_DA_001_R') this involved raising the areas in which buildings were located by 0.3m.
- 3.17 The 2D elements added, and used to adjust the DTM, for the Baseline Scenario are shown in **Figure 3.7**.



(Source: OpenStreetMap, FEH Web Service, Rappor)

Figure 3.7 2D Elements Used to Adjust Baseline DTM

2D Shapefiles

- 3.18 **Figure 3.6** shows the model schematic and GIS layers which comprise the 2D model. The watershed area (the model domain '2d_code_CRK_001_R') was determined as per the method outlined in point 3.14 above. The extent of the domain has ensured that all areas draining to the Site are accounted for, as well as areas which the Site drains to. This was done by extending the FEH catchment to ensure both the Site and key areas surrounding Site were included in the model domain.



- 3.19 The file '2d_rf_CRK_001_R' follows the domain boundary and references the percentage runoff values for the rural areas as shown in **Table 3.1**. The domain boundary is slightly urbanised.

Boundary Conditions

- 3.20 A downstream boundary condition was represented using '2d_bc_hxe_CRK_001_L'. These boundary lines were generated where surface water was indicated to be ponding along the 2D code on the Environment Agency's Surface Water Flooding map. Each boundary uses a unique calculated gradient, denoted in **Table 3.2**, to allow water to drain freely at each location.

Downstream Boundaries	Gradient
1	0.01
2	0.011
3	0.0043

Table 3.2 Downstream Boundaries

Roughness Coefficient

- 3.21 The 2D roughness values are represented within the 'Materials.csv' file referenced in the 2D read file (.TRD) which links to the model shapefile '2d_mat_CRK_001_R' and '2d_mat_CRK_007_R'. This is based on Manning's 'n' roughness values specified by Chow (1959) which is the industry standard approach. Within the 2D code, observed land uses included woodland, roads and buildings. All other space was assumed as 'pasture' with a Manning's 'n' value of 0.06, following the standard modelling approach. **Table 3.3** outlines the Manning's 'n' value for each material.
- 3.22 The materials file is largely based on the OS Open Map Local Vector Files which provides a good basis for existing land uses.
- 3.23 The roads have been modelled as a single centre line with a buffer distance of 10m applied to them to represent their width. This was checked against aerial photography and found to be suitable.

Features	Manning's 'n'
Pastures	0.06
Roads	0.022
Buildings	0.3
Woodland	0.07
Stability	1

Table 3.3 Mannings 'n' Roughness Values



Structures

- 3.24 Structures were added into the model to ensure the model was representative of what was identified within the topographic survey and on the Site visit.
- 3.25 There are several existing culverts near the site of interest, these are shown on **Figure 3.8**. Invert levels and diameters were available from the topographic survey and thus they were used to inform the model. Furthermore, the length of culverts were based on data provided in the topographic survey.



(Source: OpenStreetMap, Rappor)

Figure 3.8 Structures Included in Baseline Modelling

Model Run Parameters

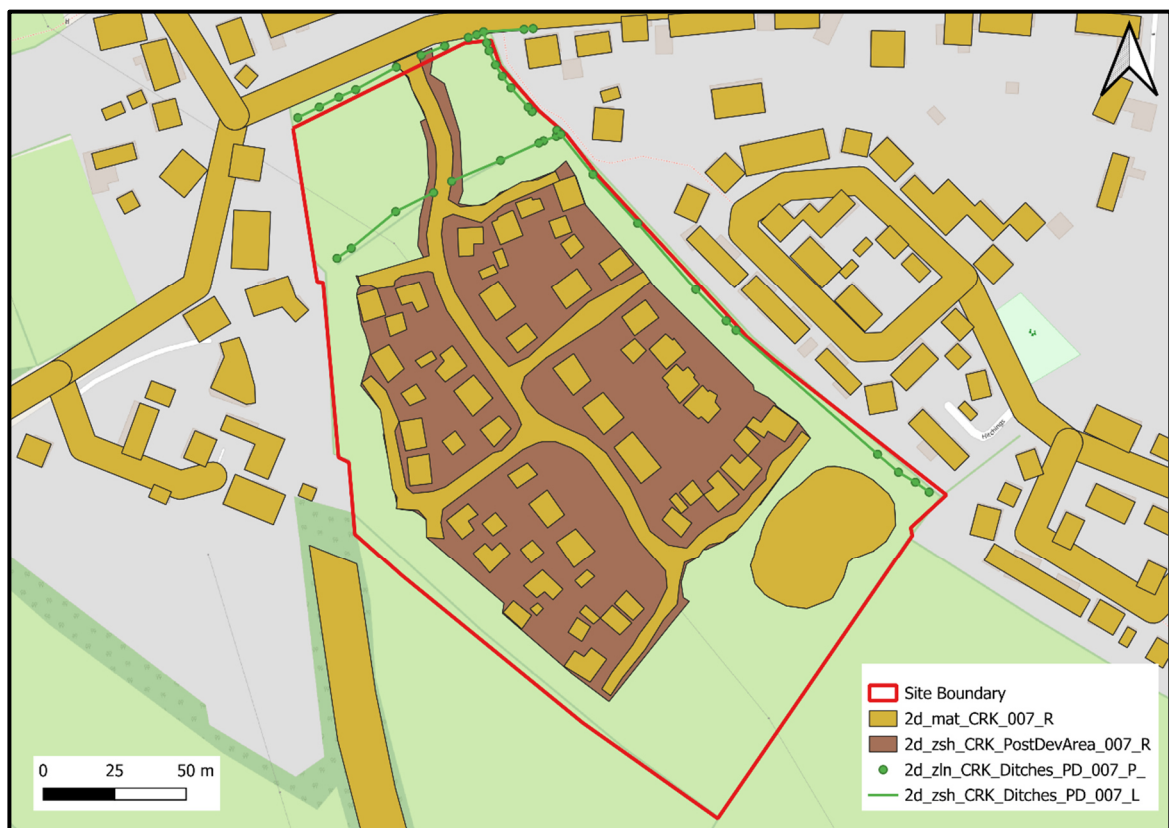
- 3.26 The model was run at a 2m grid resolution with a 1 second timestep for all events which was considered to provide an appropriate balance between model run times and resolution of results. An 8-hour run time was specified for the 1-hour rainfall events which was sufficient time to observe the runoff affecting the Site.

Post Development Hydraulic Assessment

- 3.27 Post Development Modelling was undertaken to observe how the Proposed Development (drawings shown in within the application) will influence both on and off-Site pluvial risk.
- 3.28 The baseline model parameters identified and used in the baseline modelling set out above were maintained for the Post Development scenario, with changes made to reflect the post development.



- 3.29 Changes to the model to account for the Proposed Development included the addition of proposed residential dwellings on site within the materials file and stubby buildings layer as it is understood that the existing building would be demolished.
- 3.30 The following layer was amended in the model: '2d_mat_NHT_007_R' and a new shape file was created '2d_zsh_CRK_PostDevArea_007_R' to represent the proposed layout (found within the associated application) and are shown in **Figure 3.9**. The Development area was raised to a flat elevation of 82.5mAOD.
- 3.31 Furthermore, ditches were altered slightly within the Post Development Scenario the location of the ditches remained the same as in the baseline, however, parts of the ditches were culverted where the proposed road is suggested to be constructed. An additional ditch was added that runs from west to east across site and joins the existing ditch that runs down the eastern boundary. New files were created for these ditches to reflect the culverted reaches: '2d_zsh_CRK_Ditches_PD_007_L' and '2d_zln_CRK_Ditches_PD_007_P_' and these are also shown in **Figure 3.9**.
- 3.32 As aforementioned culverts were added in the Post Development Scenario under the newly proposed road. These were added using new shape files: '2d_bc_culverts_007_PD2_P' and '1d_nwk_culverts_007_PD2_L' these are shown in **Figure 3.10**. It should be noted the culverts included in the baseline model remained in the Post Development model also (shown in pink in **Figure 3.10**).



(Source: OpenStreetMap, Rappor)

Figure 3.9 Changes Made to DTM for Post Development Scenario

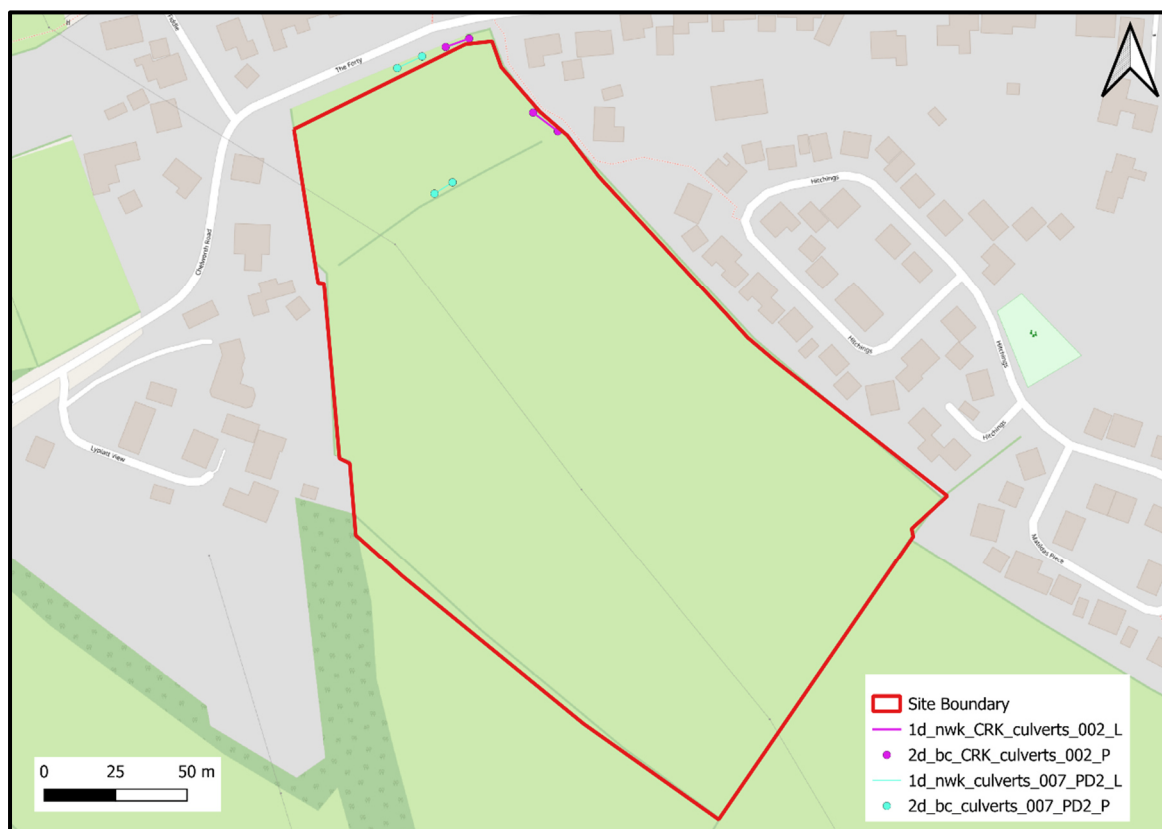
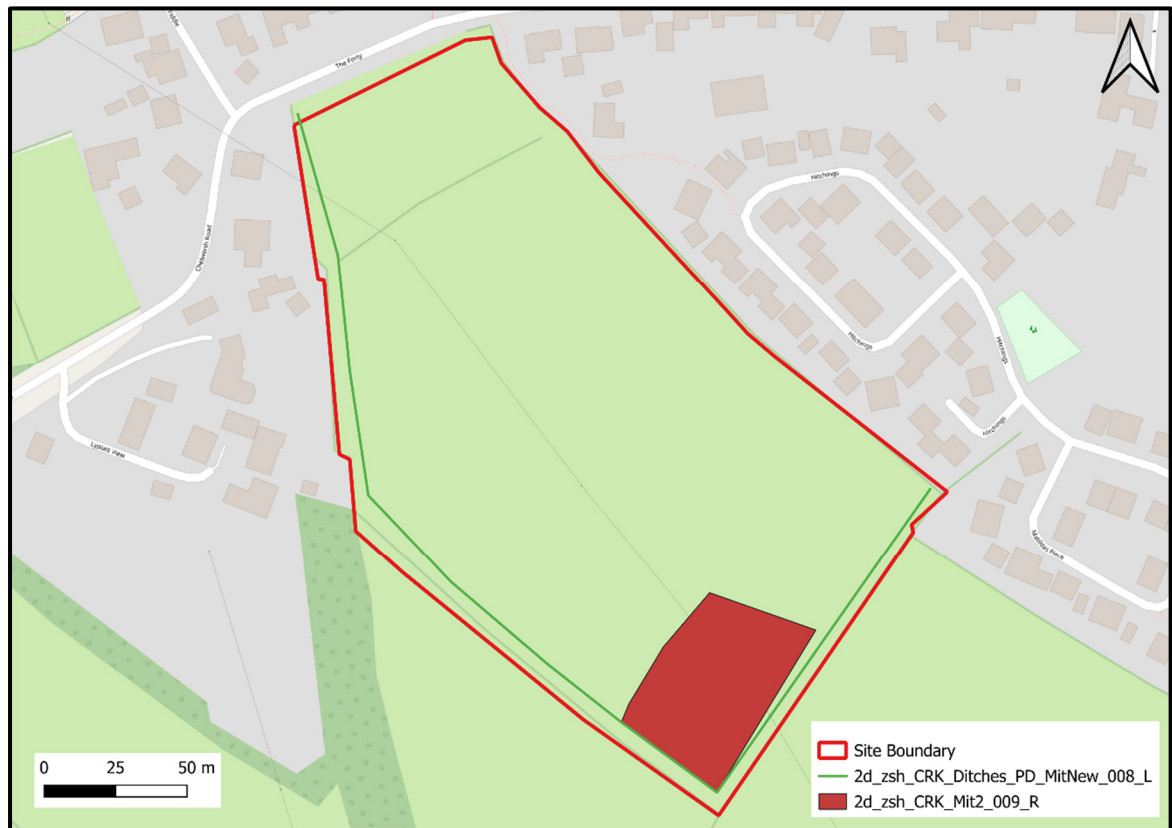


Figure 3.10 Structures Included in Post Development Modelling

3.33 Modelling to explore potential mitigation was undertaken to observe how the suggested mitigation options will influence both on and off-Site pluvial risk.

3.34 Mitigation measures included further changes to the DTM through the addition of ditches as well as the lowering of land by approximately 0.35m in the southern corner of site (all shown in **Figure 3.11**).



(Source: OpenStreetMap, Rappor)

Figure 3.11 Changes Made to DTM for Mitigation Scenario



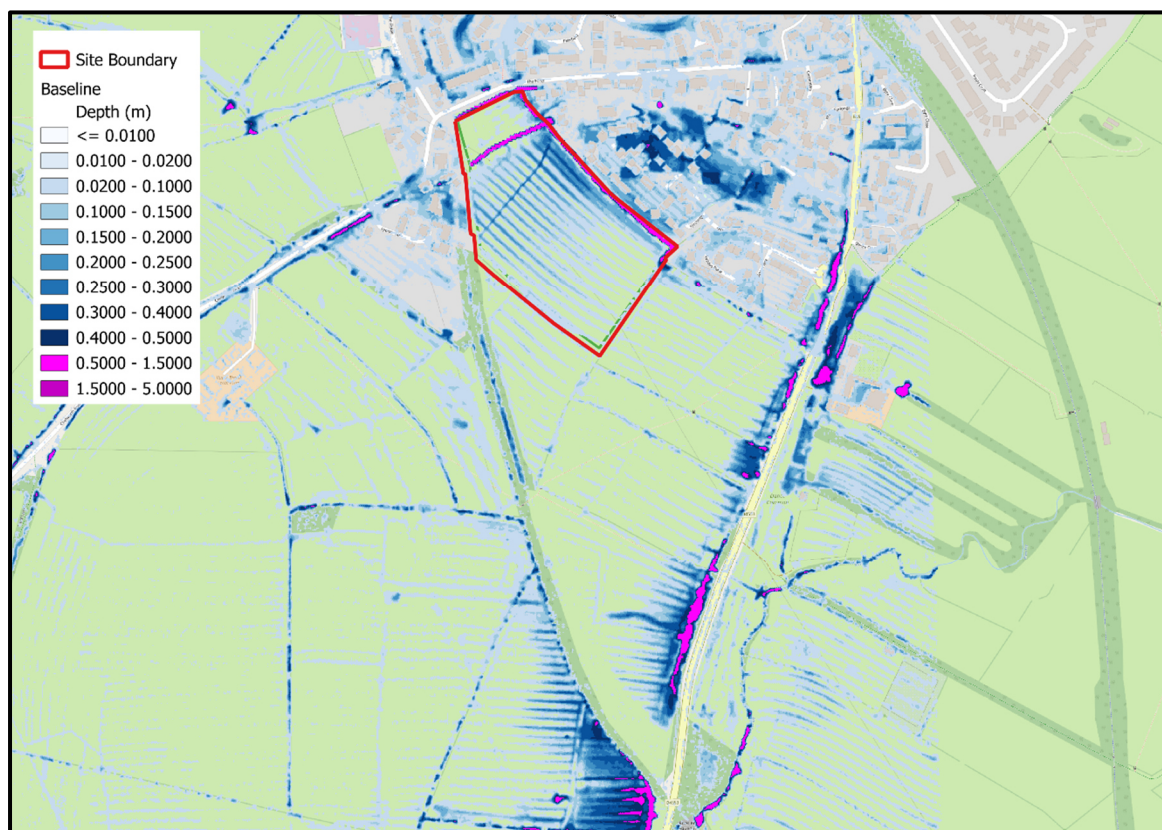
4 Results

- 4.1 The baseline scenario provides an indication of flood extents before any Proposed Development at the Site has been undertaken. This supersedes the extents and depths depicted in the catchment in the Environment Agency's Surface Water Flood Map as the rainfall runoff modelling is of higher resolution and is Site specific. This baseline scenario was also run for climate change events to understand the effects climate change has on pluvial risk to the Site of interest.
- 4.2 The extent and depths of flooding for the design event inclusive of climate change (1 in 100-year event plus 40% climate change) flood event is then outlined with the associated mapping provided. This event has been selected for results analysis as it is in line with NPPF and PPG and is the required Design event.
- 4.3 For all results the design event (1 in 100 year plus 40% climate change allowance) is outlined. This firstly shows the amount of pluvial risk experienced by the site, and surrounding area, prior to any development taking place.
- 4.4 Post Development results are then provided for the design event to allow for analysis of the impact of the Proposed Development on pluvial risk for both the Site itself and the area surrounding Site.
- 4.5 Results then go on to outline the impact mitigation techniques have on ensuring pluvial risk is managed both on site and ensuring there are no determinate off site impacts of the development on pluvial risk.
- 4.6 A difference map has also been produced to allow the change in pluvial risk, as a result of the proposed developed, to be identified.



Baseline Results

- 4.7 Surface water flooding depths and extents for the 1 in 100-year plus 40% climate change flood event in the baseline scenario is illustrated in **Figure 4.1**.



(Source: OpenStreetMap, Rappor)

Figure 4.1 Baseline 1 in 100-Year Plus 40% Climate Change Allowance (Design Event) Model Outputs

- 4.8 The outputs from the baseline modelling have provided outlines that are largely similar to those shown on the EA's surface water mapping. Whilst the patterns are generally the same, the modelling undertaken by Rappor show, in the main, there is a slight increase in extents and depths.
- 4.9 Depths on site are modelled by Rappor to reach maximum depths of 0.45m for the majority of the site, with the existing ditches on site shown to hold water with depths of up to 0.9m. The patterns of surface water risk of site are also modelled to be relatively similar to the EA's mapping with the surface water ponding located 300 m south of site reaching depths of up to 0.85 m.

Post Development Results

- 4.10 For the Post Development modelling, representative of the proposed development, the pluvial patterns of risk on Site change considerably as a result of the proposed erection of buildings on Site (**Figure 4.2**). The development platform on site is shown to push risk to the northern section of the development. Depths in the northern portion of site, in the absence of development were shown to reach a maximum of 0.25m (close to the eastern



boundary **Figure 4.1**). In the post development scenario pluvial flood risk is shown to be a lot wider in this northern portion of site with depths shown to reach up to circa 0.6m.

- 4.11 In the absence of mitigation measures pluvial risk is shown to increase in the area 300 m south of site as depths are shown to increase to 0.91.

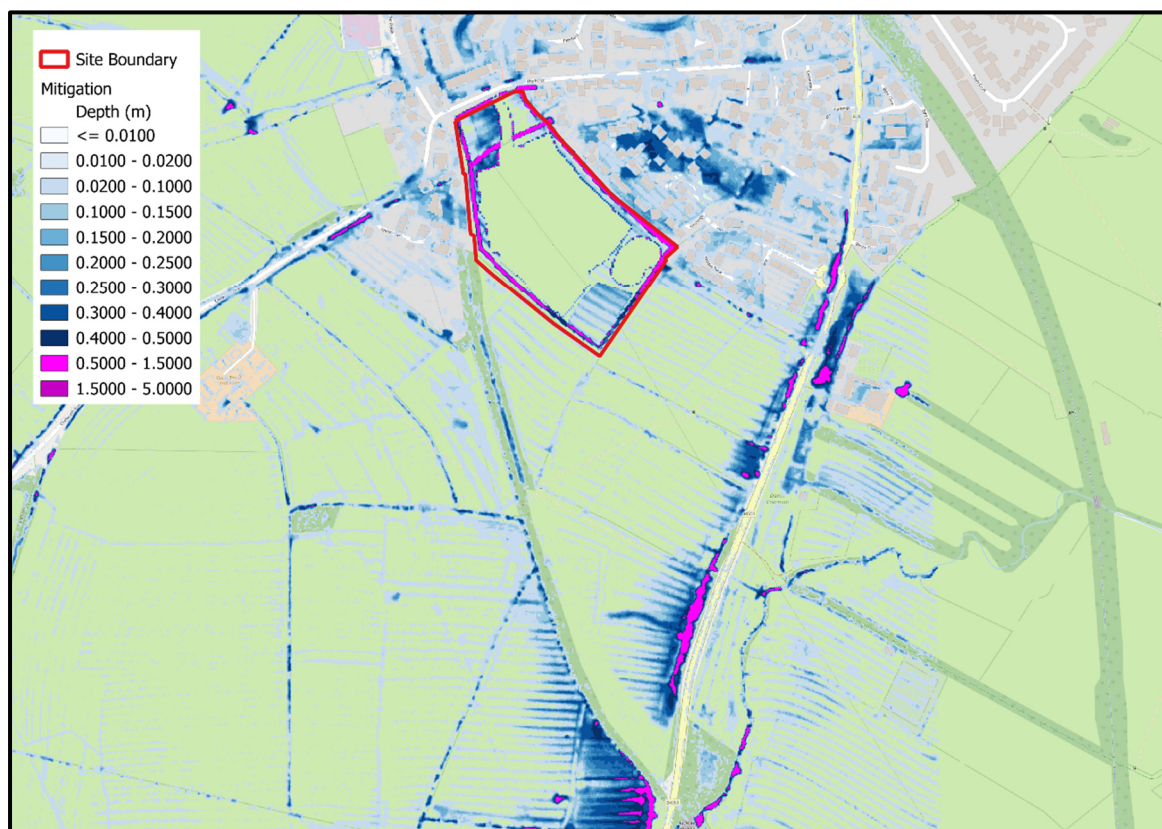


(Source: OpenStreetMap, Rappor)

Figure 4.2 Post Development 1 in 100-Year Plus 40% Climate Change Allowance (Design Event) Model Outputs

Mitigation Results

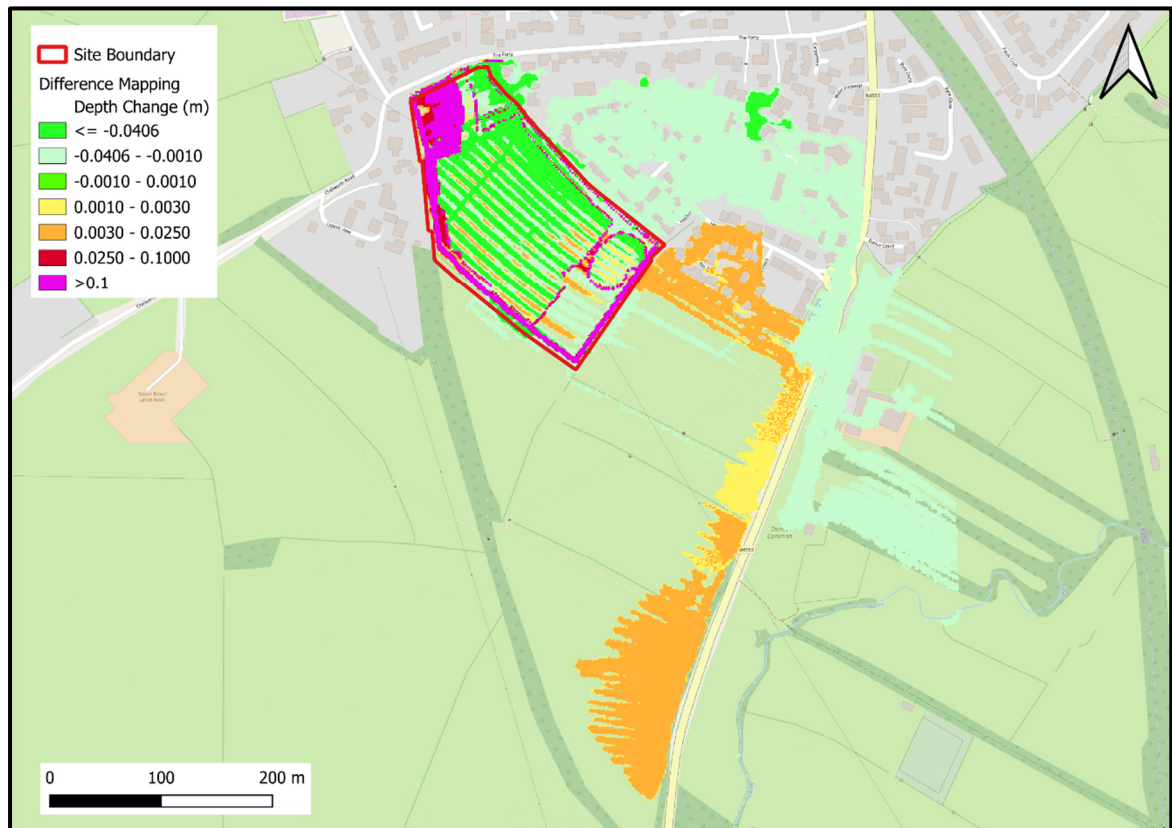
- 4.12 The mitigation measures (addition of a ditch that runs down both the western and southern boundary and the addition of a 0.35m depression located in the southern corner of site) are also shown to cause changes to the pluvial risk on site. Firstly, water is shown to be stored within these ditches as well as more water being collected in the artificially produced low point located in the south of site. The addition of water in these areas has meant pluvial risk in the north of site has been reduced in both extents and also depths. Depths have been shown to reduce to circa 0.35m in the north of site (**Figure 4.3**).



(Source: OpenStreetMap, Rappor)

Figure 4.3 Mitigation 1 in 100-Year Plus 40% Climate Change Allowance (Design Event) Model Outputs

- 4.13 Furthermore, off site increases in pluvial risk have been modelled to decrease considerably when mitigation measures are included in modelling. However, there are still some minor off-Site increases because of the post development, even when mitigation measures are included. Whilst extents are shown to remain the same compared to the baseline depths have been shown to increase slightly. These increases are particularly noted north and east of site. However, following consultation with the LLFA these depths have been shown to be minor increases and deemed to be within model tolerance given the assumptions and limitations within the modelling (see later section), increasing by a maximum of 0.017 m. The change in pluvial risk as a result of the proposed is illustrated with a difference map (**Figure 4.4**).
- 4.14 It should also be noted, the Proposed Development is modelled to create a betterment in pluvial risk to existing developments, particularly in the residential areas located northeast of site (as shown in **Figure 4.4**).



(Source: OpenStreetMap, Rappor)

Figure 4.4 Post Development vs Baseline Difference Map for Design Event

Sensitivity analysis

- 4.15 Sensitivity analysis was undertaken for the design event (1 in 100 year plus 40% climate change) to understand the impact of roughness parameter selection on modelled results at the Site of Interest. Manning's 'n' roughness was altered in the 2D domain for a 20% increase and 20% decrease in roughness values.
- 4.16 The water level change at the Site of interest ranges from -0.668 to 0.159m. Whilst there is some change noted in sensitivity testing, values selected during the model build process use industry standard values and Chow 1959 guidance.

Limitations and Assumptions

- 4.17 The results of hydraulic models are largely dependent on the accuracy of the hydrological and topographical/geometry data included in the model. While the most appropriate available information has been used to construct the model there are associated uncertainties and limitations with it. Effort has been made to limit the level of uncertainty to meet the objectives of this study and sensitivity analysis has been undertaken where appropriate.
- 4.18 There are uncertainties associated with the hydrological methods of small drainage catchments (<5km²), and runoff calculated by models with an initial storage component (such as the PDM model used in ReFH) may be very sensitive to storage parameters and initial conditions. Total runoff estimates may therefore be uncertain, however appropriate effort was made to reduce uncertainty surrounding this including applying a Percentage



Impermeable (PIMP) value as used in the Wallingford procedure. In addition, surface water drainage networks have not been represented in the model and infiltration has not been represented in the surface water model; this is considered a conservative approach.

- 4.19 Hydraulic roughness estimates are based on land-use according to aerial imagery, Site specific survey photographs, Site visit observations and modeller experience and is a simplification of the real-world situation. It is not possible to achieve the level of detail to capture the full range of complex hydraulics that would be likely to occur on the ground and as such, this approach is considered appropriate and applicable. The roughness values are based on available guidance (Chow, 1959). The roughness value may vary over the year and as such sensitivity analysis (as set out above) was undertaken to quantify the impact.
- 4.20 To calibrate any model data from suitable flow and level gauges is required with quality historical flows and spatial information showing the extents of major flood events. No gauge data is available within the model domain to calibrate the models.
- 4.21 The downstream boundary for the 2D model domain is located a sufficient distance from the Site of interest and therefore this should not impact results at the Site of interest.

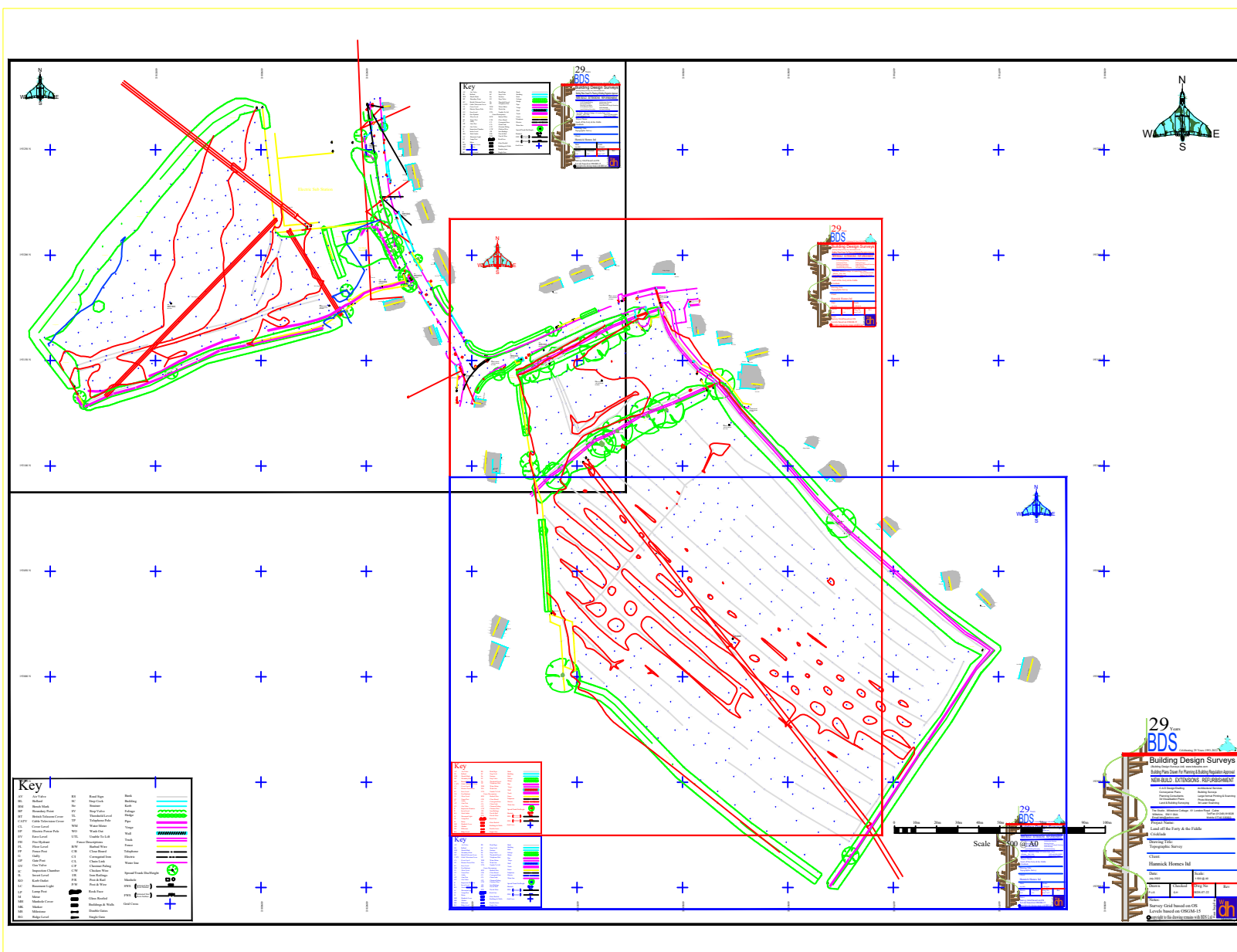


5 Conclusions

- 5.1 This Technical Note has provided details of the 2D Direct-Rainfall model which has been undertaken by Rappor Consultants Ltd on behalf of Hannick Homes.
- 5.2 The Baseline scenario provides an indication of flood extents before any Proposed Development at the Site has been undertaken. This supersedes the extents and depths depicted in the catchment in the Environment Agency's Surface Water Flood Map as it has a higher resolution.
- 5.3 Results show compared to EA mapping extents of pluvial risk generally increase, however, have ensured the identified ditches are included. Modelling by Rappor suggests these ditches can hold water up to depths of 0.9m.
- 5.4 The Post Development scenario is representative of the Proposed Development and has been produced to assess the impact of the development on flood risk to both Site and the surrounding area. Post Development modelling shows a change in pluvial risk both on and off Site. The difference map has illustrated that there is an increase in pluvial flood risk on Site, particularly in the south, as a result of the proposed development. The Post Development modelling illustrated the need for mitigation measures to decrease the changes in off-site pluvial risk.
- 5.5 Mitigation measures involved modelling the addition of several ditches as well as dropping an area in the southwestern corner by 0.35m.
- 5.6 These measures we shown to be successful at both reducing pluvial risk on site but also ensuring off-site increases are kept to a minimum and are within acceptable model tolerance (as deemed acceptable following initial conversations with the LLFA). Therefore, mapping has shown off site increases to be minor reaching maximum increases of 0.017m. It should be noted that the Proposed Development, with the inclusion of mitigation measures, has led to a betterment in pluvial risk to many existing developments.



Appendix A – Topographic Survey



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Rappor Consultants Ltd

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