Land at Breinton Lee, Hereford

Cotswold Oak Ltd

Hydraulic Modelling Technical Note

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Rappor Consultants Ltd
A: CTP House, Knapp Road, Cheltenham, GL50 3QQ
W: www.rappor.co.uk
T: 01242 523696
E: hello@rappor.co.uk

Executive Summary

This Hydraulic Modelling Technical Note has been produced on behalf of Cotswold Oak Ltd in respect of a planning application for a residential development on land south of Kings Acre Road, Breinton Lee, Herefordshire.

Current Environment Agency (EA) mapping shows that the site is identified to have a low to high risk of surface water flooding. This is indicated to be aligned with an overland flow path originating from the west of the site, along with topographical depressions providing areas for surface water to pool.

Surface water flooding has been confirmed through discussions with Herefordshire County Council (in their role as the Lead Local Flood Authority (LLFA) as the dominant form of flood risk to the site, and as such, detailed modelling to confirm the risk and the potential impact of the proposed development is required. This requirement was also required owing to known historic incidents of flooding in and around the site.

In order to meet the requirements of the LLFA, Rappor Consultants Ltd have undertaken hydraulic modelling through a direct rainfall runoff model to confirm the level of surface water risk, assess the impacts of the proposals, as well as identifying and assessing potential alleviation works to reduce any elevated risks.

Three scenarios have been modelled (at the request of the LLFA), a baseline scenario which confirms the level of surface water risk. This modelling exercise confirmed the extent of flooding at the site and showed that this is greater than shown on the Environment Agency flood map; however, the associated depths and risk are considered low. Additionally, this modelling also confirmed the mechanisms was not because of flows from the west as first thought and instead from the south - this is discussed further in the report.

A ‘Do Nothing’ scenario, in which the proposed development was included within the model, prior to any flood mitigation measures being included. This indicated that the development would reduce the risk of flooding to the dwellings and the road directly north of the site; however, a slight increase in flooding would occur in the flood extent along the site’s southern boundary and to third party land. Despite this, the increased flooding shown was localised and of shallow depths which were within model tolerance levels and can therefore be considered acceptable. The overall flooding within the site increased, due to there being dwellings and roads providing areas for surface water to pool, although these areas would be minimised in practice as the proposed drainage system would capture and direct these flows elsewhere.

The third scenario was a ‘Post Development’ scenario, which is similar to the ‘Do Nothing’ scenario but includes flood mitigation measures. These measures included an extended drainage ditch designed to capture more flows along the south of the site, and reprofiled ground levels in this area to provide further attenuation benefits within the site and help remove any increase in flood risk off-site and, where possible, provide a betterment to the existing baseline. In addition to this, the attenuation basins proposed as part of the site’s drainage strategy also provide further storage for capturing runoff, which will help contain runoff on site and particularly benefit the low return period events. These changes provided slight reductions in the flooding seen along the southern boundary when compared to the ‘Do Nothing’ approach, but the extents seen in this area remained similar to those in the baseline scenario. Reductions in flood extents and depths were seen around the dwellings and King’s Acre Road north of the site, as a result of the proposed development holding runoff within the site.

The above approach has been discussed and agreed with the LLFA as a suitable approach.

Overall, this modelling exercise has confirmed that the proposed development will not result in an adverse increase in flood risk to the area in the site's direct vicinity.

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1 Introduction

Background

1.1 The purpose of this Hydraulic Modelling Technical Note is to assess the current risk of surface water flooding to the proposed development, any impact to risk the development may cause, and identify, where possible, risk alleviation measures which could be incorporated as part of the development.

Site Proposals

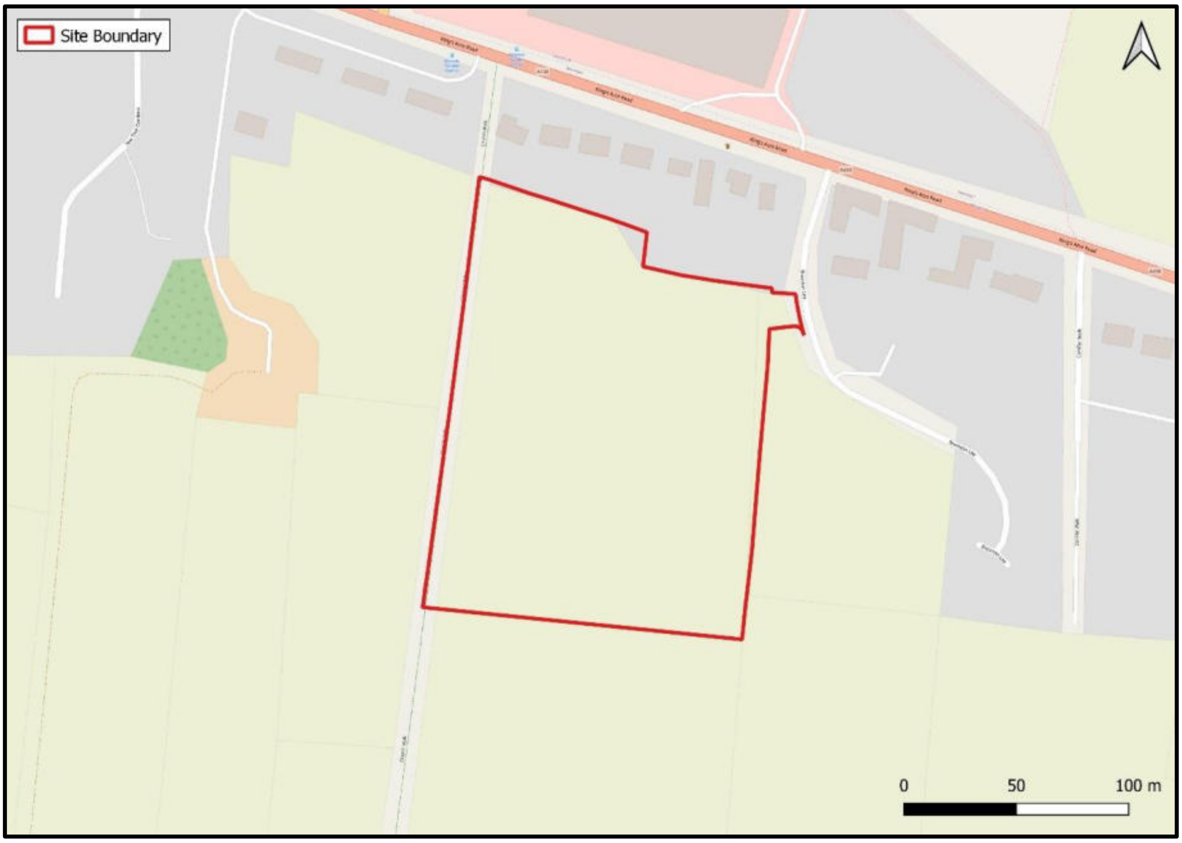
1.2 The proposed development includes for the construction of up to 45no. residential properties with associated access and landscaping.

1.3 A copy of the proposed development drawings is included within **Appendix A**.

2 Existing Site & Hydrology Characteristics

Site Location & Composition

2.1 The site is located to the west of Breinton Lee and to the south of Kings Acre Road (A438), approximately 2.4 miles west of Hereford City centre. The approximate site co-ordinates for the centre of the site are E: 347163; N: 241336, with the nearest post code of HR4 0SN. The approximate location of the site is shown outlined in red on **Figure 2.1**. The approximately 2.5ha development area on site currently comprises of arable, greenfield farmland.



(Source: OpenStreetMap, Rappor)

Figure 2.1 Site Location

Topography

2.2 A detailed topographic survey was carried out during June 2021 and again in July 2022, a copy of which is included within **Appendix B**. Ground levels on the development area within the site generally fall to the east, although the ground along the centre of the site is at a higher level creating a crest and resulting in ground levels falling north and south from the centre. Levels fall from 70.37 metres Above Ordnance Datum (mAOD) in the centre of the site's western boundary to 69.28mAOD located in the north-eastern corner of the site and 69.13m in the south-eastern corner.

2.3 An existing ditch is present along the site's eastern boundary which has been picked up in the topographical survey. Freely available LiDAR data further confirms its presence.

2.4 **Figure 2.2** displays the topographical survey data within the site boundary, in the form of a hillshade raster layer. This illustrates how levels fall to the east, but the site is generally seen to be flat.

(Source: OpenStreetMap, Coombes: Everitt Architects)

Figure 2.2 Topographical Survey

3 Hydrological and Hydraulic Assessment

Background

3.1 **Figure 3.1** displays the Environment Agency's (EA) Surface Water Flood risk mapping at the site. This indicates low to high risk areas of flooding across the site.

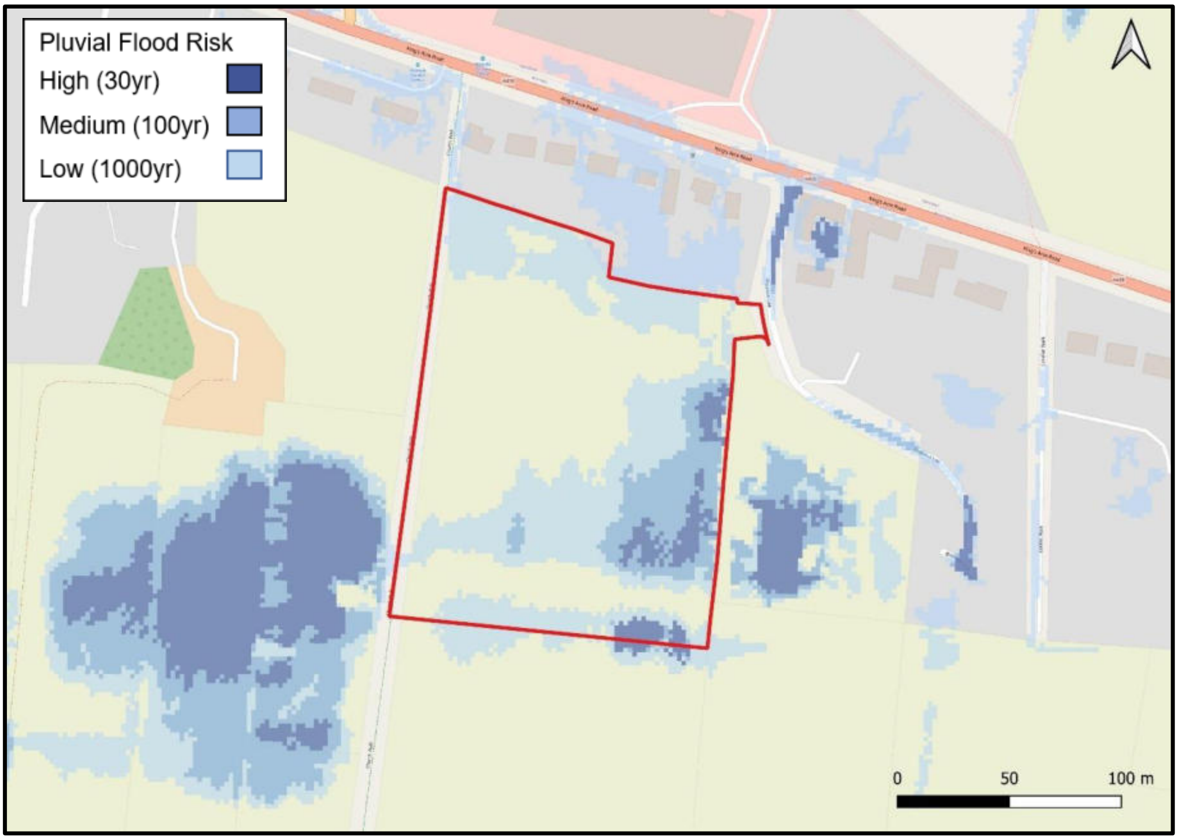
3.2 A low risk surface water flow path originating from an area of high risk flooding to the west of the site is projected to flow east across the site. Areas of medium to high risk flooding are shown to occur along the site's eastern boundary aligned with this flow route. High risk flooding can also be seen in the southwest of the site aligned with an area of lower topography, with lower risk flooding extending towards the site's western side.

3.3 In the north of the site, low risk flooding is indicated to be present, with flows in this area being shown to be directed north towards King's Acre Road.

3.4 In the 1% AEP design flood event, depths of flooding within the site are seen to be 150-300mm deep, with some increased depths of 300-600mm shown in the ditch along the eastern boundary, **Figure 3.2**.

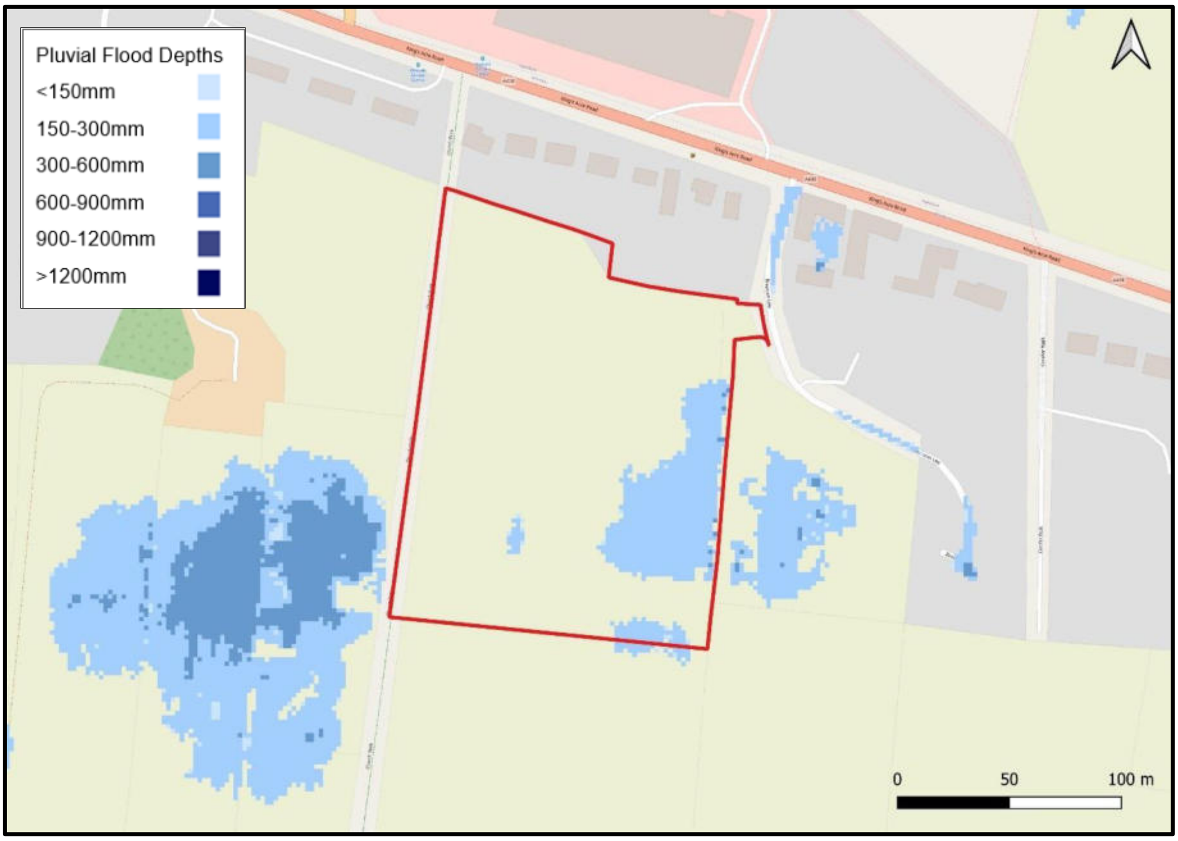
3.5 In light of the above, discussions with the applicant and Herefordshire County Council have identified the need for a detailed rainfall run-off model to provide detailed assessment of the surface water risk at the site.

3.6 As such, Rappor Consultants Ltd have undertaken detailed rainfall run-off modelling to assess the impact of the identified surface water flooding across the site utilising a direct run off hydraulic model in TUFLOW.



(Source: OpenStreetMap, Environment Agency)

Figure 3.1 Environment Agency Surface Water Flood Extents



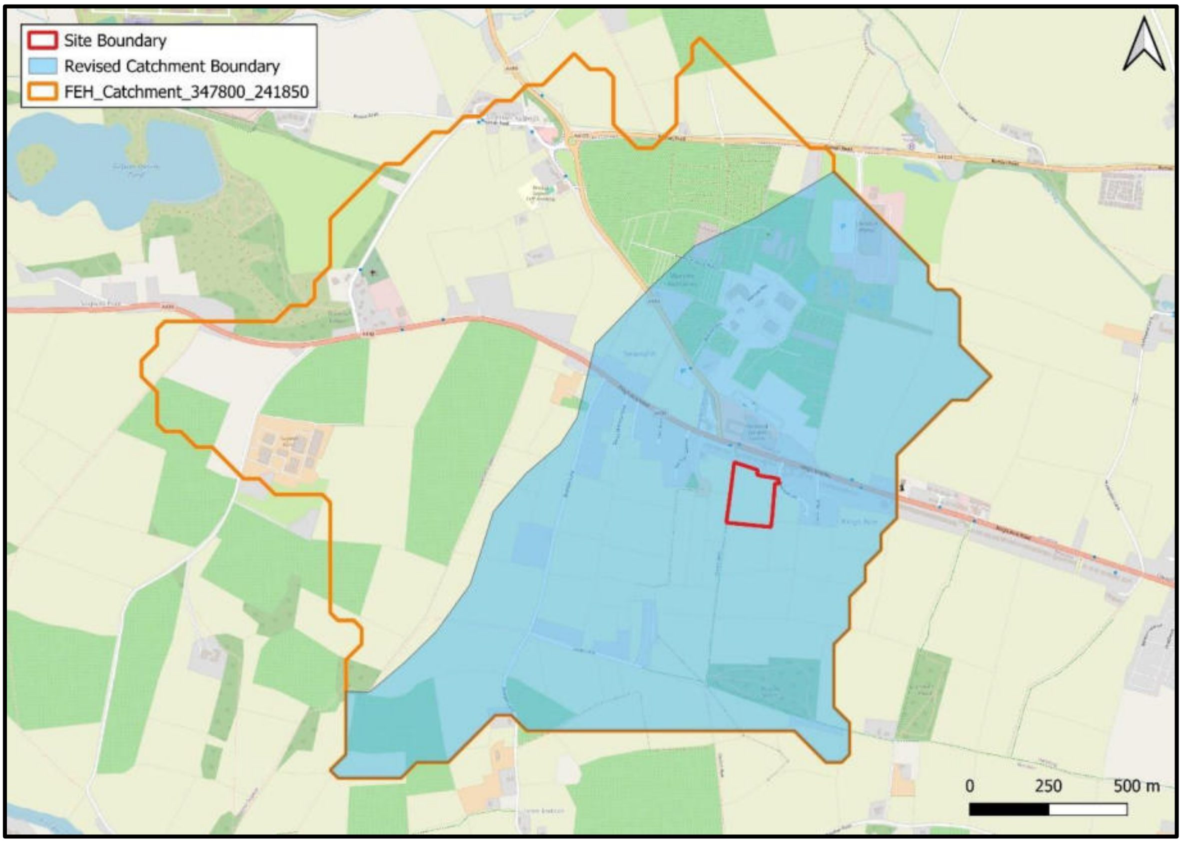
(Source: OpenStreetMap, Environment Agency)

Figure 3.2 Environment Agency Surface Water Flood Depths (1% AEP Event)

Flood Catchment Boundary

3.7 The drainage catchment for which the site lies within is illustrated in **Figure 3.3**. This is identified as FEH_Catchment_347800_241850. Following an initial run of the baseline model, the size of the drainage catchment was reduced within the model to the extent shown as the “Revised Catchment Boundary” in **Figure 3.3** to aid with model run times. This was deemed appropriate as the flow routes within the original catchment which were now excluded from the model were not shown to have been connected to any flows within the “Revised Catchment Boundary.”

3.8 The area of the catchment was reduced from 3.78km^2 to 2.00km^2. The outflow coordinates of the catchment (347800, 241850) remained the same.



(Source: OpenStreetMap, FEH Web Service, Rappor)

Figure 3.3 Catchment Boundaries

Rainfall Modelling

Rainfall

3.9 Rainfall depths are derived from the FEH DDF (Depth Duration Frequency) model with catchment parameters taken from the FEH Web Service from an outlet point, grid reference 347800, 241850.

3.10 The 1 in 5-year, 1 in 30-year, 1 in 100-year and 1 in 100-year plus 45% climate change allowance storm events have been modelled following agreement with the LLFA. Each of the events have been run for a storm duration of 6.5 hours, which is over the 6 hour required storm length for calculating runoff volume as specified in guidance documents.

3.11 The events considered critical for the surface water drainage design are the 1 in 30-year and 1 in 100-year plus climate change. The 1 in 30-year is the typical design standard under Sewers for Adoption where no flooding of the system should occur. The 1 in 100-year plus climate change, for which a 45% allowance is required in this catchment, event 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. The 1 in 5-year event has been run to represent the expected conditions in more commonly occurring storm events.

Run-off Calculation

3.12 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 Soilscapes as “freely draining slightly acid loamy soils”. The entire catchment has an SPRHOST value of 38.04%, indicating a just below average permeability.
b) Small drainage catchments can result in small rainfall depths. 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.

3.13 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 0.109., the overall Percentage Runoff was calculated as 45.4% (0.454). The site itself is rural with an urban area to the north.
c) All catchment descriptors have remained the same for the revised catchment as they were for the original catchment.
d) It has been assumed that for the purpose of the direct rainfall modelling that no water enters the sewer system. This is considered to be 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.
e) The results of applying these methods are summarised in **Table 3.1** and can be viewed in **Figure 3.4**.

(Source: OpenStreetMap, FEH Web Service, Rappor)

Figure 3.4 Urban/Rural Catchment De-lineation

Method	Percentage Run-off Values
SPRHOST (from FEH Data)	38.04% (0.3804)
PIMP weighted rural/urban	10.9% (0.109)

Table 3.1 Runoff Parameterisation, Rural and Urban

Baseline Hydraulic Assessment

Model Type

3.14 Based on the identified requirement to consider overland flow routes, a linked 2D model has been developed using TUFLOW HPC v2023-03-AC. This was run in double precision to follow standard guidance for direct run-off modelling.

Model Grid

3.15 The 2D model is based on a detailed topographical survey for ground levels within the site, which was undertaken in July 2022, and LiDAR data (flown in 2022 at 1m resolution) to represent ground levels for the rest of the wider catchment. The final grid files referenced by the model are 'grid\Topo_DEM.asc' for the topographical survey, and 'grid\SO44se_DTM_1m.asc' for the LiDAR data.

3.16 In addition to this, a levels master plan undertaken in April 2024 was undertaken and used to provide detailed survey of the finished floor levels of the proposed residential development. This was utilised for the 'Do Nothing' scenario to represent the impact of the proposals to surface water flooding before any additional alleviation measures were considered. This grid file is referenced by the model as 'grid\FFL_01.asc'.

3.17 Following the results of the 'Do Nothing' model run, an updated levels plan was produced with revised ground levels and a flood alleviation measure in the form of a ditch along the southern boundary to reduce the impacts of the development, this is further discussed in Section 4, and represents the 'post development' scenario. The reference for this grid file is 'grid\FFL_003.asc'. The finalised levels plan is illustrated in the Drainage Strategy drawing within the accompanying Flood Risk Assessment (Report Reference: 21-0503-FRA).

2D Shapefiles

3.18 **Figure 3.5** shows the model schematic and GIS layers which comprise the 2D model. The watershed area (the model domain '2d_code_BLE_002_R') was determined as per the method outlined in point 3.7 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.

3.19 The file '2d_rf_BLE_002_R' follows the domain boundary and references the percentage runoff values for the rural areas as shown in **Table 3.1**. The site is considered to be rural with the northern boundary just extending into an urban area which bounds the site.

(Source: OpenStreetMap, Rappor)

Figure 3.5 2D Model Schematic

Boundary Conditions

3.20 Three downstream boundary conditions were represented using ‘2d_bc_hxe_BLE_002_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	0.00305
2	0.00635
3	0.0093

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_BLE_002_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, buildings, ponds and other structures. 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 6m 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
Ponds and Other Water	0.03
Woodland	0.07
Railway Track	0.04
Vegetated Creek	0.08

Table 3.3 Mannings ‘n’ Roughness Values

Model Run Parameters

3.24 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 6.5-hour rainfall events which was sufficient time to observe the runoff affecting the site.

4 Results

4.1 The model has been run for three scenarios.

4.2 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.

4.3 The 'Do Nothing' scenario illustrates the effect of the proposed development on surface water flooding within the catchment, with no further flood alleviation measures taken into account. The attenuation basins and additional drainage ditch along the eastern boundary within the site proposed as part of the drainage strategy have been accounted for within this scenario, but no positive drainage from these features occurs in the model.

4.4 The 'Proposed Development' scenario represents the impact of the development on surface water flooding in the catchment when flood alleviation measures within the site are accounted for. The flood alleviation measures which have been proposed as part of the development include reprofiled ground levels in the southeast of the site and the extension of the additional ditch present along the side's eastern side down towards and along the south of the site to further capture overland flows. The ditch is approximately 300-400mm deep. Again, there is no positive drainage from the ditch within the model; however, once developed it is proposed to discharge runoff captured in the ditch to ground via infiltration.

4.5 The proposed mitigation measures with their associated levels are included within the Drainage Strategy drawing within the accompanying Flood Risk Assessment and Drainage Strategy (Report Reference: 21-0503-FRA).

4.6 The extent and depths of flooding for the 1 in 100-year plus climate change flood event are outlined and compared in below for each scenario, with the associated mapping also provided. In addition to this, analysis of the flooding seen in the 1 in 5-year event is also compared between each scenario, to reflect the impacts of the most frequent rainstorms.

4.7 Mapping of the extent of flooding in this event across the catchment, and the 1 in 5-year, 1 in 30-year, 1 in 100-year events are contained within **Appendix C**.

4.8 In each of the events there is limited change in the extents and depths of flooding outside of the site boundary, as a result the below commentary focuses on the impacts seen within the site and its direct vicinity.

Baseline Results

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

4.10 The modelling has shown the flood waters which pool to the west of the site, does not cross the footpath and enter the site which differs from the current EA mapping. The crest level of the footpath is high enough to hold back water in the land to the east of the site. This is a result of the model utilising a higher resolution than the Environment Agency mapping allowing it to pick up changes in elevation in greater detail.

4.11 The large area of flooding seen within the site is indicated to be caused by a topographical depression and ground levels falling towards the ditch along the site's eastern boundary. Depths of flooding in this area are greatest to the east of the site, with depths of up to 0.20 - 0.25m seen in some small areas but the majority of flooding shown to be 0.05 - 0.1m deep. This is considered to pose a low to medium risk.

4.12 The 1 in 100-year modelled extents, contained within **Appendix C**, are slightly greater than those in the Environment Agency's 1 in 100-year flood mapping, but depths are shown to be marginally lower with the Environment Agency mapping showing depths of 150 – 300mm across the flood extent whilst the detailed mapping shows depths of 0.05 – 0.1m.

4.13 Greater depths of flooding can be seen within the ditch in comparison to the rest of the site, 0.3-0.4m, in both the 1 in 100-year and 1 in 100-year plus climate change events; however, these flows are contained within the ditch and do not spread out to the land to the east of the site. The Environment Agency surface water flood maps do not identify any flooding in the ditch, due to the lower resolution of the modelling.

4.14 Along the site's southern boundary, overland flows from the field south of the site flow north towards the site's southern boundary and pool. Depths are shown to be between 0.1 – 0.15m at their deepest in the 1 in 100-year plus climate change event. In comparison to the Environment Agency surface water flood mapping, the detailed modelling shows greater flood extent in both the 1 in 100-year and the 1 in 100-year plus climate change events.

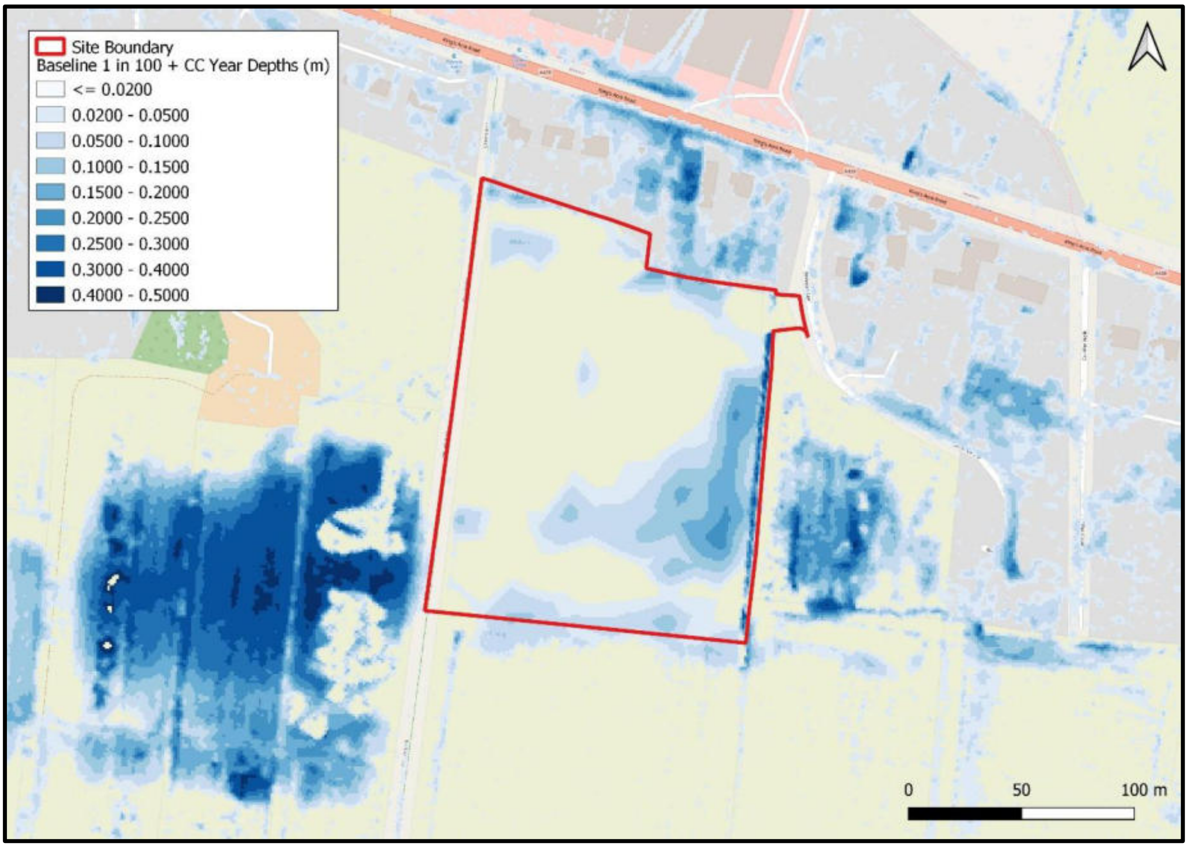
4.15 In the north of the site, there is not shown to be any flooding in the Environment Agency surface water mapping, whereas in the baseline model there is shown to be some low depth flooding in areas of lower topography. Towards the east of the northern boundary a flow route is identified to be present, with flows directed north towards King's Acre Road where pooling occurs (which aligns with known flooding issues). This is the only point where flow paths originating within site are connected to areas of flooding outside of the site boundary, the areas of flooding within the south are a result of pooling in an area of low topography rather than overland flows. Flows generated within the site can therefore be considered to have minimal influence on flooding across the wider catchment.

4.16 There is not identified to be any flooding which would pose access or egress issues from the site at the accessway.

4.17 The extents and depths of a more frequent flood event, 1 in 5-year, are provided in **Figure 4.2**. From this it can be seen that flooding within the site predominantly occurs in two main areas, along the eastern boundary and along the south, as identified in the 1 in 100-year plus climate change event. Flooding in these areas is shown to be of low depths, with peaks of 0.1 - 0.15m shown in small areas.

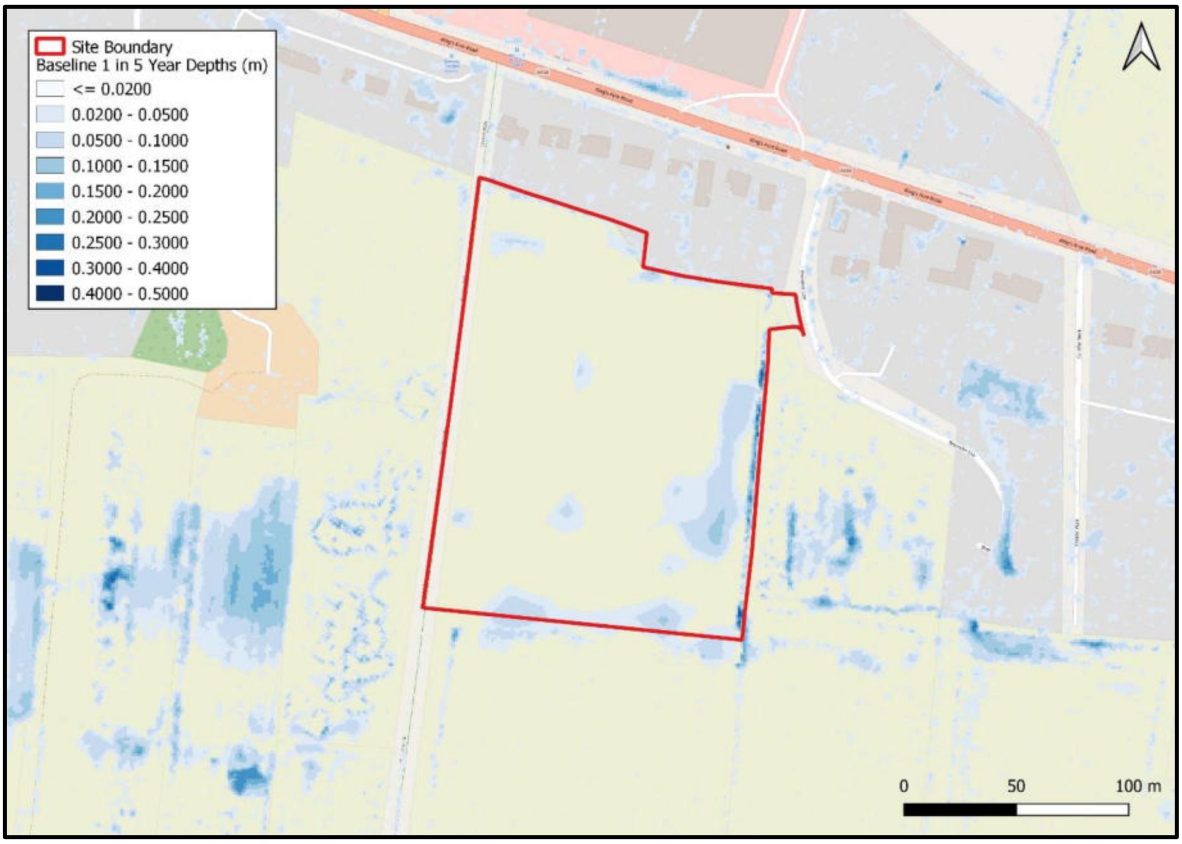
4.18 Flooding extents in, and around, the ditch in the eastern boundary in the 1 in 5-year event are lower than in the 1 in 100-year plus climate change event but depths of flooding remain consistent, 0.3 – 0.4m.

4.19 Overall, the risk posed to the site during the 1 in 5-year and 1 in 100-year plus climate change events is considered to be low to moderate and with effective mitigation measures implemented, such as raised finished floor levels, the development would be deemed at low risk.



(Source: OpenStreetMap, Rappor)

Figure 4.1 Baseline Modelled 1% AEP + CC Flood Extents and Depths



(Source: OpenStreetMap, Rappor)

Figure 4.2 Baseline Modelled 20% AEP Flood Extents and Depths

‘Do Nothing’ Results

4.20 **Figure 4.3** illustrates the depth of surface water flooding across the site during the 1 in 100-year plus climate change event in the ‘Do Nothing’ scenario.

4.21 When comparing the results of the 1 in 100-year plus climate change flood event between the ‘Do Nothing’ scenario and the baseline scenario, the total extent of flooding across the site is greater in the ‘Do Nothing’ scenario. This is due to the presence of the proposed buildings, roads, and attenuation basins and ditch (associated with the proposed drainage strategy) creating areas for runoff to pool. As aforementioned, the modelling does not account for positive drainage from the proposed drainage system for the site which will, in reality, reduce the extents of flooding shown.

4.22 The extents of flooding along the site’s southern boundary are slightly greater in this scenario when compared to the baseline, extending marginally further into the field beyond the site’s southern boundary. The depths of flooding shown in the additional flooded areas are low, ranging from 0.02 – 0.1m, and hence their overall impact would be minimal particularly given they occur within greenfield land. These depths present a worst case scenario and could be attributed to model tolerance and therefore considered insignificant.

4.23 Where these flood extents lie in the south of the site these are to be utilised as Public Open Space as part of the development. As a result, the increased extent of flooding within the site would not have detrimental impact to the users of the site and would not increase risk to the proposed dwellings. Depths of flooding in this area, within the site, do not exceed 0.15 – 0.2m and are considered of low risk.

4.24 Areas of flooding to the north of the site, including the flow route towards King’s Acre Road, have smaller extents in the ‘Do Nothing’ scenario than in the baseline scenario. This indicates that the development reduces the risk of flooding to these dwellings and King’s Acre Road.

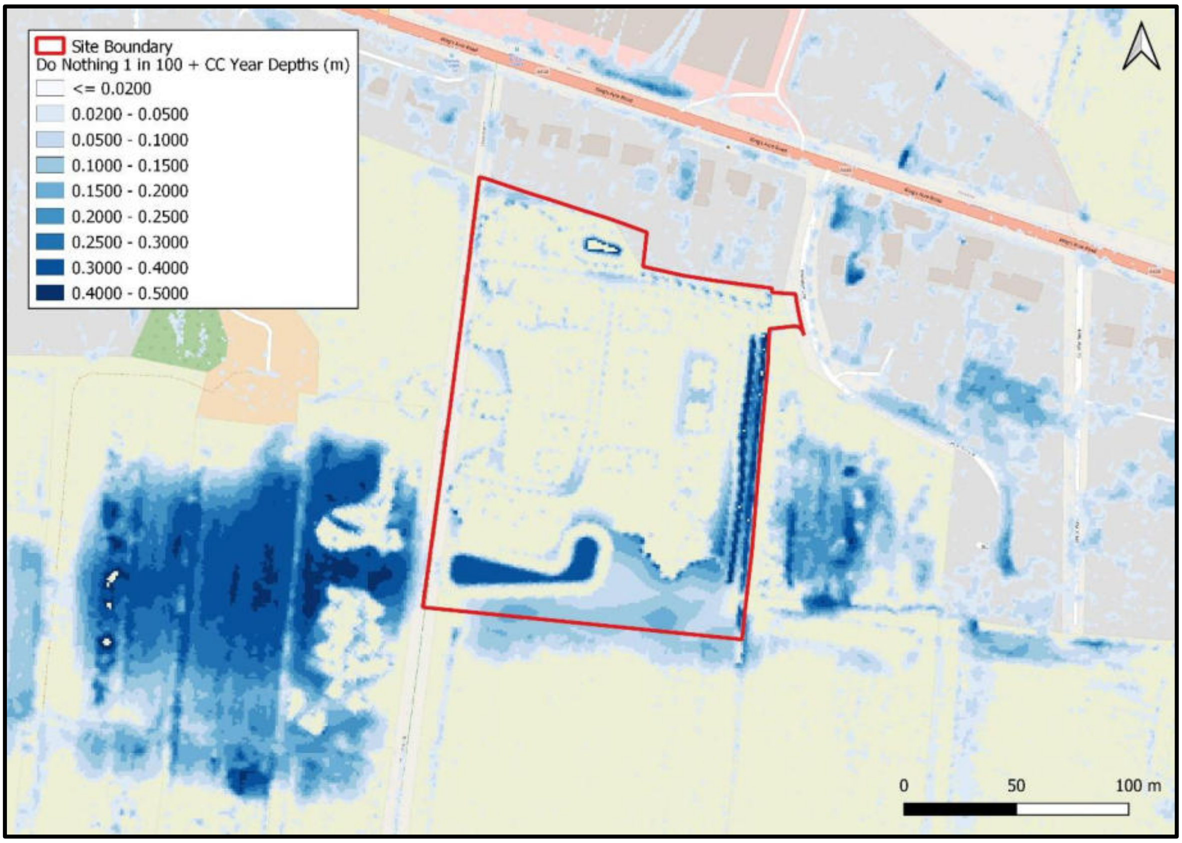
4.25 The inclusion of the ditch along the site’s eastern boundary, which is part of the proposed drainage strategy not a specific flood alleviation measure, has inherently helped to reduce the extents of flooding within this area compared to that shown in the baseline scenario. The depths of flooding in the existing ditch remain the same, 0.3 - 0.4m. In the ‘Do Nothing’ scenario the depths of flooding in the surface water drainage strategy’s drainage ditch are greater than those in the existing ditch in the same scenario, showing that the additional flows collected reduce the volume required to be held in the existing ditch.

4.26 **Figure 4.4** illustrates the extents and depths of flooding in the 1 in 5-year event for the ‘Do Nothing’ scenario.

4.27 In the 1 in 5-year flood event, there is minimal difference in extents and depths of flooding shown when comparing the ‘Do Nothing’ and baseline scenarios, aside from the ponding occurring within the site due to the proposals. The area of flooding along the southern boundary is shown to be of the same extent and depths in the ‘Do Nothing’ scenario as in the baseline. Extents of flooding shown to the north of the site in the dwellings along King’s Acre Road are reduced in the ‘Do Nothing’ scenario.

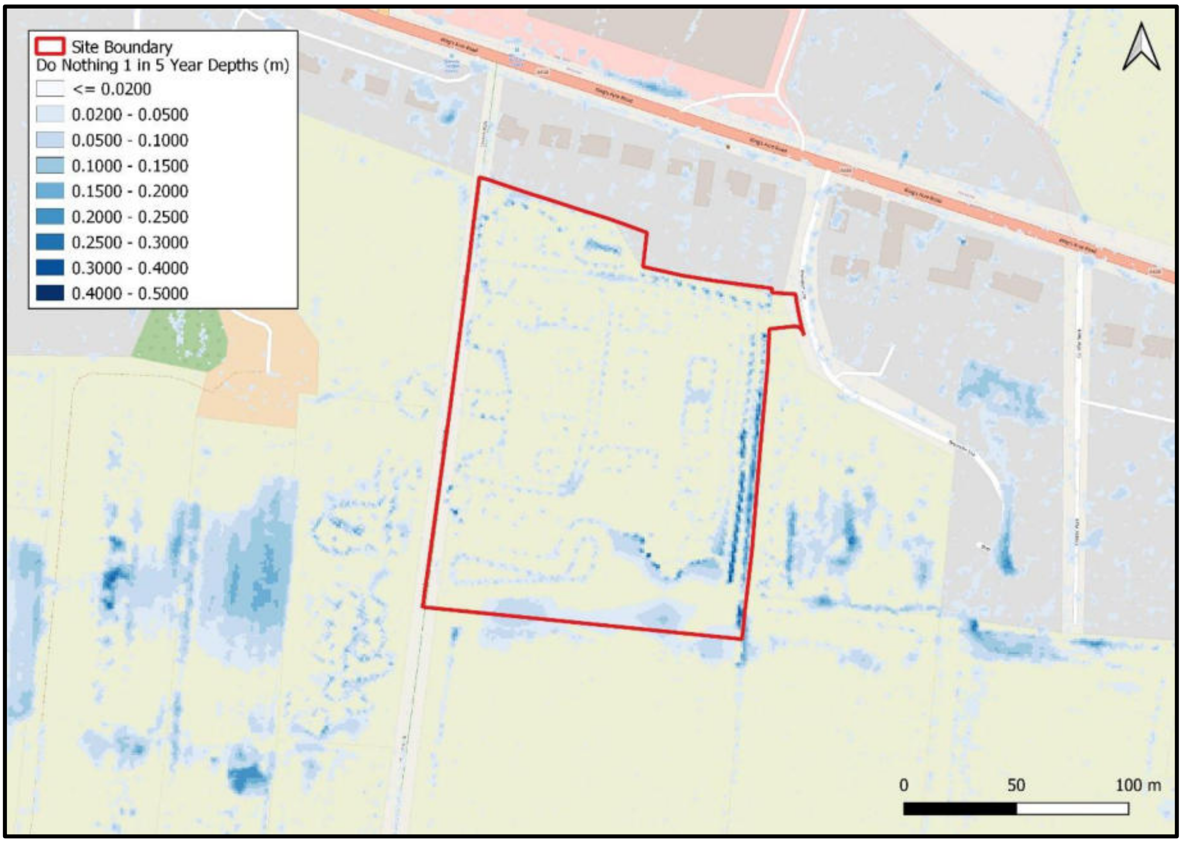
4.28 When comparing the extents and depths of flooding between the ‘Do Nothing’ and baseline scenario for the 1 in 5-year and the 1 in 100-year events, the overall risk within the site has increased with more ponding occurring. The extent and depths of flooding outside of the site boundary is reduced in the north, benefitting the dwellings directly north of the site. But there are small increases in depths around the area of flooding along the southern boundary in the field to the south.

4.29 In summary the changes seen in the 'Do Nothing' scenario in comparison to the baseline scenario reflect a reduced risk in the north benefitting the wider catchment, but a minimal increase in risk in the flooding in the south and as a result require the mitigation measures proposed in the 'Post Development' scenario to reduce this impact.



(Source: OpenStreetMap, Rappor)

Figure 4.3 Do Nothing Modelled 1% AEP + CC Flood Extents and Depths



(Source: OpenStreetMap, Rappor)

Figure 4.4 Do Nothing Modelled 20% AEP Flood Extents and Depths

'Post Development' Results

4.30 **Figures 4.5**, **4.6** and **4.7** display the extent and depths of flooding in the 1 in 100-year plus climate change event for the 'Post Development' scenario which accounts for mitigation measures included. These measures include the extension of the second ditch on the east of the site down towards the south through the proposed area of Public Open Space and reprofiled ground levels in the southeast. The location of these measures is shown in **Figure 4.8**.

4.31 **Figures 4.6** and **4.7** display results from calculations comparing the depths of flooding seen in 'Post Development' scenario against the baseline and 'Do Nothing' scenarios. Where changes in depths could be due to model tolerances, -0.02 - 0.02m, the results of the calculations have been removed from the comparison Figures.

4.32 As illustrated on **Figure 4.6** in comparison to the baseline scenario, the 'Post Development' scenario indicates a decrease in flood depths in areas to the north of the site. Depths around the dwellings to the north and in their rear gardens, and along King's Acre Road, are shown to be as high as -0.1 – -0.5m.

4.33 To the south of the site, some localised increases in depths are shown around the extent of the flooding along the site's southern boundary. These increases in depths are very shallow, within the 0.02 – 0.1m range, and are therefore deemed to be within model tolerance levels. As a result, these changes are not deemed significant and are acceptable.

4.34 Across the site itself, there is mostly shown to be an overall reduction in flood depths when comparing the post development scenario to the baseline. Greater depths of flooding can be seen along the ditch present on the site's eastern boundary when comparing the 'post development' scenario to the baseline.

4.35 The extent of flooding in the land to the east of the site is unchanged when comparing the 'Post Development' and baseline scenario extents. This is also true for the flooding shown to occur along the accessway.

4.36 As shown by **Figure 4.7**, the 'Post Development' scenario shows an overall reduction in flooding across the site in comparison to the 'Do Nothing' scenario. Some increased flooding of depths 0.02 – 0.1m can be seen in the southeast of the site; however, as aforementioned this is within an area of Public Open Space and has been designed to provide additional storage and will have no impact on the development.

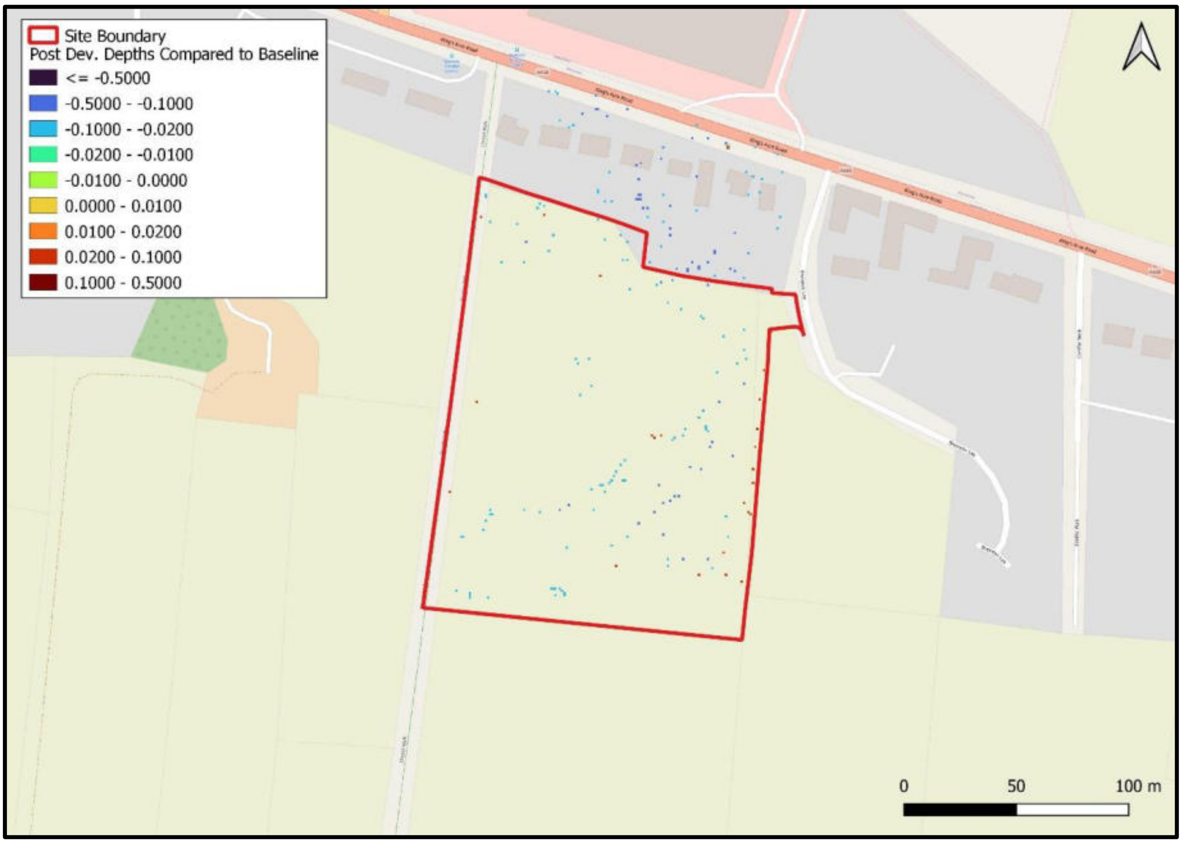
4.37 The 'Post Development' scenario reduces the amount of flooding within the site around the southeastern most dwellings, where ground levels have been reprofiled. In addition to this, through the proposed extension of the ditch, the depths of flooding along the southern boundary and in the field to the south of the site have fallen from 0.1 – 0.15m in the 'Do Nothing' scenario to 0.1 – 0.05m and lower in some areas. The overall extent of the flooding has remained similar.

4.38 In the 1 in 5-year event, the differences in flooding depths and extents between the 'Post Development' and 'Do Nothing' scenarios are minimal. The extension of the additional drainage ditch in the 'Post Development' scenario has reduced flooding to the south of it and the reprofiled ground levels have reduced ponding in the area north of the extended section of the ditch. The results of the modelled flooding for this event are shown in **Figure 4.9**.

4.39 In summary, the 'Post Development' scenario indicates that the proposals will result in a decrease in flooding in the area to the north of the site benefitting the dwellings there, as well as reducing the risk of flooding to King's Acre Road. Within the site itself, the proposals will help to reduce the risk of surface water flooding, with runoff able to pool within the site before it is captured by the proposed surface water drainage strategy. The area of flooding along the site's southern boundary and within the field to the south is shown to have some small, localised increases in depths; however, these are shown to be very shallow and within model tolerance levels which are deemed acceptable. The overall risk of flooding within the site with the proposed development is considered low.

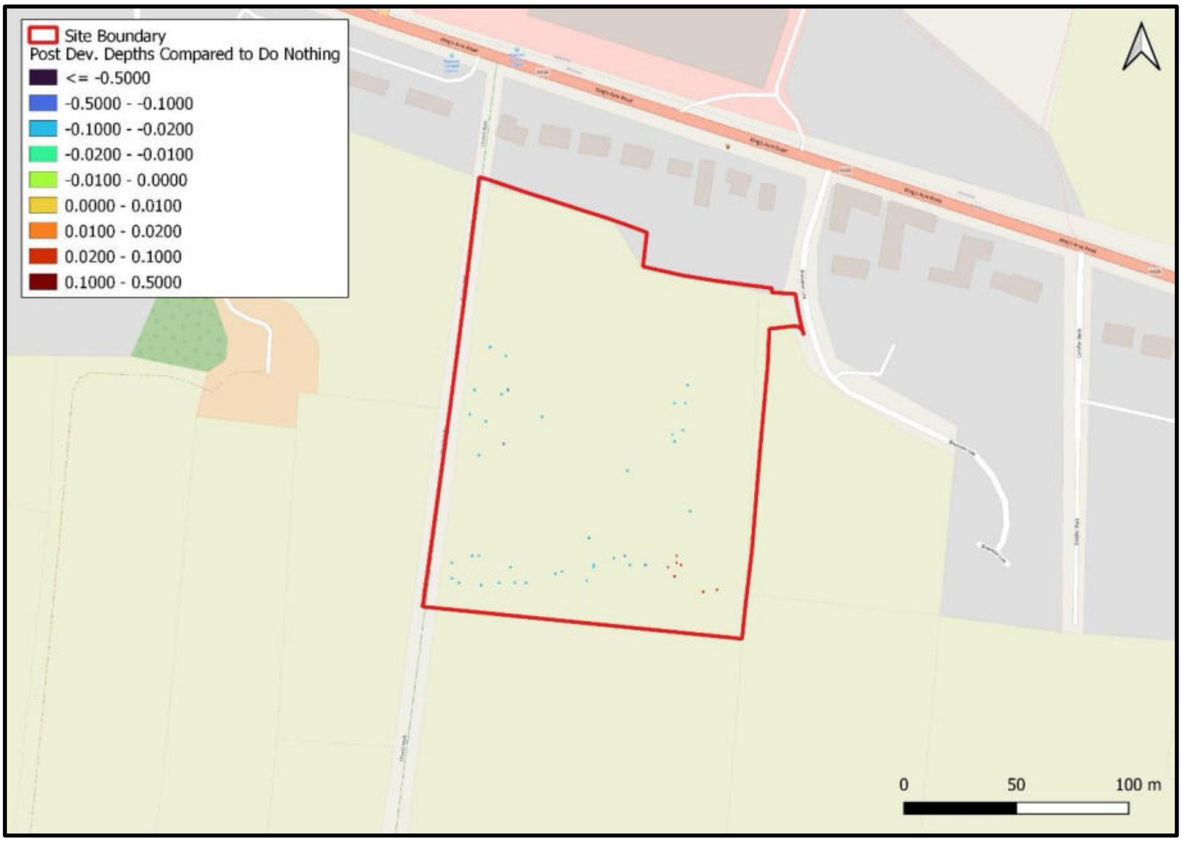
(Source: OpenStreetMap, Rappor)

Figure 4.5 Post Development Modelled 1% AEP + CC Flood Extents and Depths



(Source: OpenStreetMap, Rappor)

Figure 4.6 Post Development Compared to Baseline 1% AEP + CC Flood Depths

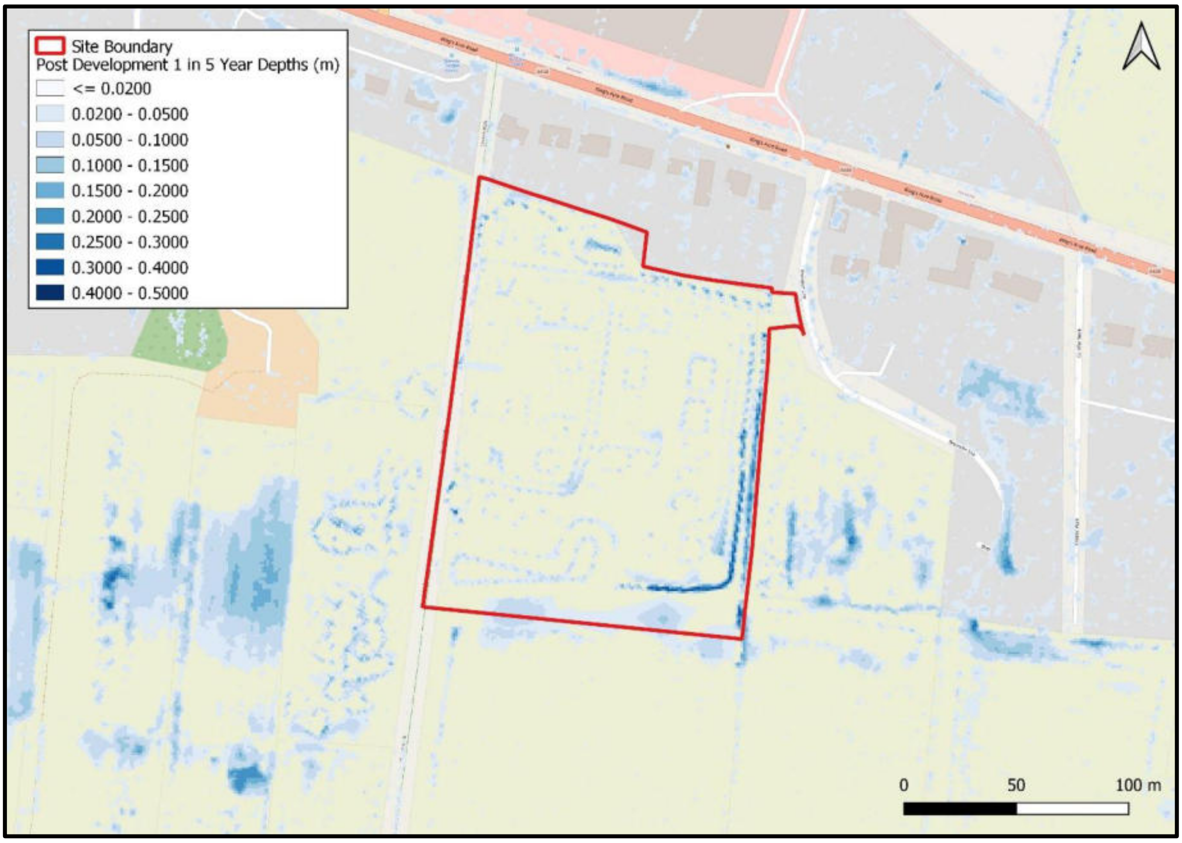


(Source: OpenStreetMap, Rappor)

Figure 4.7 Post Development Compared to Do Nothing 1% AEP + CC Flood Depths

(Source: OpenStreetMap, Rappor)

Figure 4.8 Post Development Flood Mitigation Measures



(Source: OpenStreetMap, Rappor)

Figure 4.9 Post Development Modelled 20% AEP Flood Extents and Depths

Model Stability

4.40 On review of the model log file, the following warnings were output during the simulation of the Post Development 1 in 100-year plus climate change flood event:

Warning 2218 - Manning's n value of 1. for Material 99 (Stability) is unusually low or high

Warning 2583 – Material ID 3 (Stability) has a manning's n value greater than Wu limit

Warning 2583 – Material ID 99 (Buildings) has a manning's n value greater than Wu limit

WARNING 2550 - 1 instability timestep correction

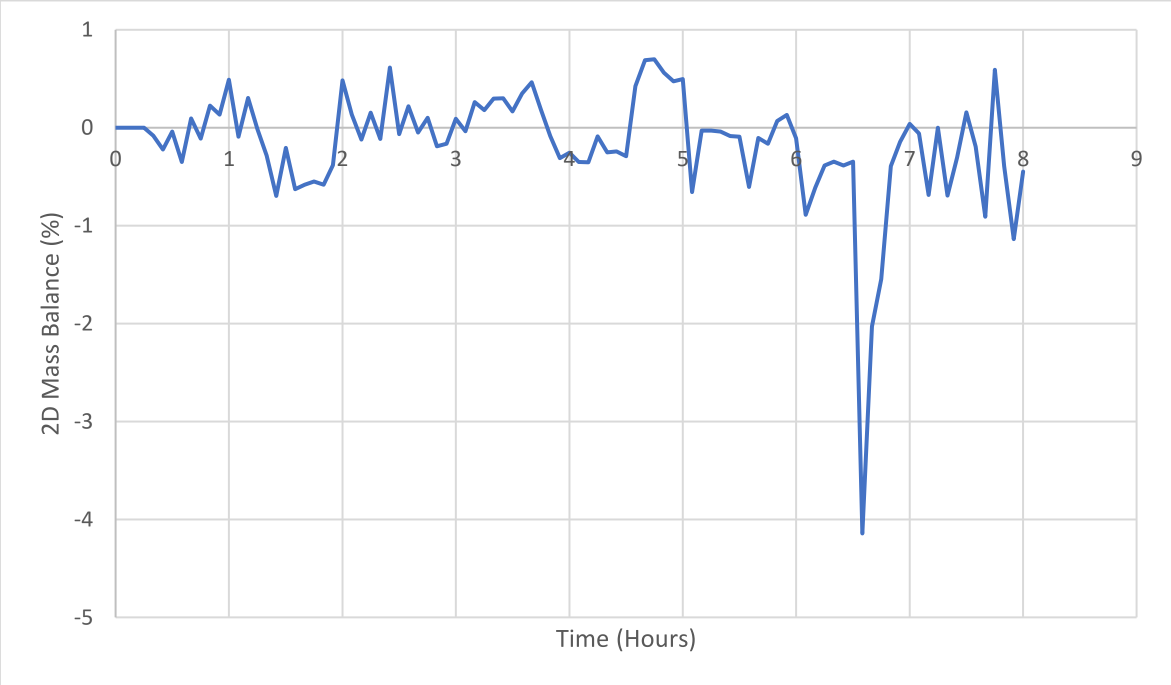
4.41 These associated warnings are considered to have minimal influence on the results of the model. As previously denoted, the Mannings 'n' values used within the model are specified by Chow (1959) which is the industry standard approach.

4.42 Warning 2550 reflects the instability of the model when low depths of flooding are present. During the 1 in 5-year event across each scenario, there were multiple Warning 2550's due to the low depths of flooding in the model as a result of the low inflows from the corresponding flood event. This is not considered to have a significant impact on the model results.

4.43 No negative depths occurred throughout the simulation and the results seem sensible with no extreme spikes in levels across the area of interest.

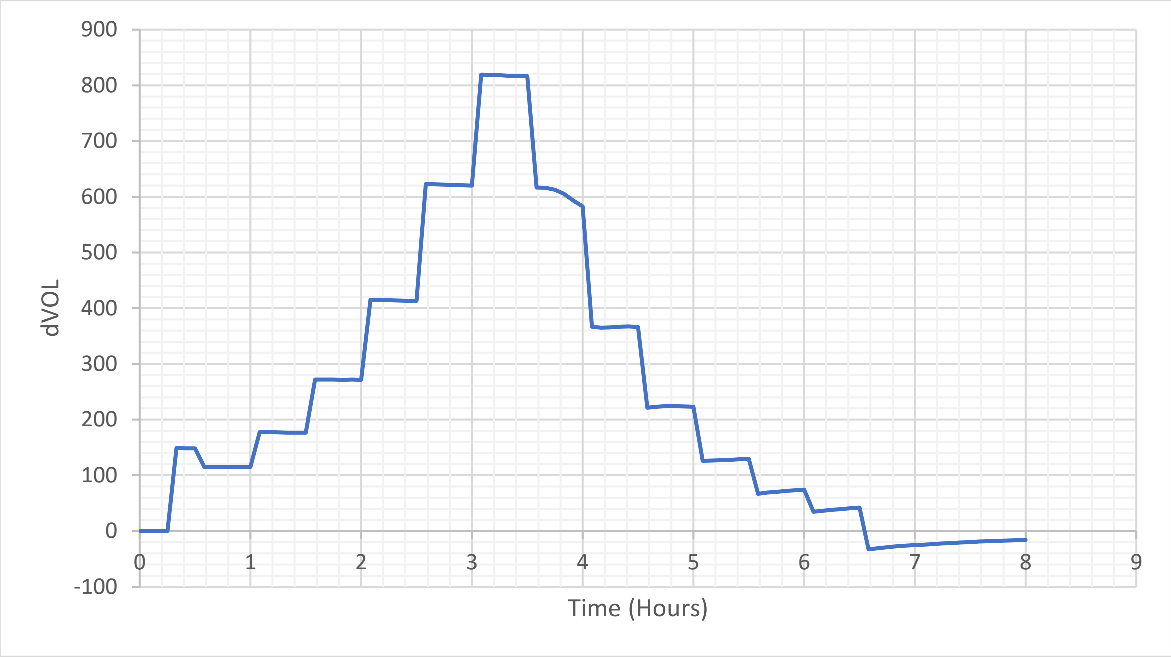
4.44 **Figure 4.10** displays a review of the model 2D Mass Balance output during the 1 in 100-year plus climate change simulation. This shows the models mass balance to lie within the ±1% tolerance across the majority of the run. There is a very short drop in mass balance, for approximately 6 minutes when flows are below the peak and continuing to decrease; however, the model then restabilises for the remaining 1.5 hours of the model, and it can therefore be concluded to be stable.

4.45 The dVol across the model run time is shown to spike every half an hour, which is consistent with the specified rainfall inputs. This is illustrated in **Figure 4.11**.



(Source: Rappor)

Figure 4.10 2D Mass Balance 1 in 100-year Plus Climate Change



(Source: Rappor)

Figure 4.11 dVol 1 in 100-year Plus Climate Change

5 Conclusions

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 Cotswold Oak Ltd due to the potential risk of surface water flooding identified at Land at Breinton Lee, Hereford.

5.2 Direct rainfall models were undertaken for three scenarios; baseline, 'Do Nothing', and 'Post Development'. The baseline model was used to confirm the depths and extents of surface water flooding in the site in its existing state. The Environment Agency surface water mapping indicates low to high risk of flooding at the site; however, the baseline 1 in 100-year plus climate change flood event modelled extents and depths indicated a lower risk, with the predominant areas of risk shown to be in the east and south of the site. The results of the baseline model supersede the Environment Agency surface water mapping, as they have a higher resolution.

5.3 The 'Do Nothing' scenario utilised surface data for the proposals within the site, as well as the attenuation basins and drainage ditch associated with the proposed drainage strategy but without any positive discharge, prior to any mitigation measures being incorporated. The results of this scenario model indicate that the proposals may result in a slight increase in the extent of flooding along the site's southern boundary, resulting in the need for flood mitigation measures in the 'Post Development' scenario to address this. The results did show that the proposals would reduce the extent and depths of flooding to the area to the north of the site, benefitting the dwelling's located there and King's Acre Road.

5.4 In the 'Post Development' scenario, the development and the proposed flood mitigation measures were included in the model. These mitigation measures comprise reprofiled ground levels around plots in the southeast of the site and the extension of the drainage strategy's drainage ditch, towards and along the southern extent of the site. These measures resulted in the reduction in the risk of flooding to the area north of the site and a reduction in flood depths within the site. Around the flooding at the site's southern boundary, some very shallow and localised increases in flood depths were seen, but as they are so shallow they are within model tolerance levels and deemed insignificant.

5.5 Across each of the modelled flood events, the risk of flooding was not altered across the catchment, other than the changes seen in the site's direct vicinity as outlined previously outlined. Therefore, the proposed development is considered to have a negligible negative impact on the wider catchment and small but noteworthy benefit to the catchment, reducing flooding to the residential area located directly north of the site and can therefore be considered acceptable from a flood risk perspective.

Appendix A – Proposed Development Drawings

Accommodation Schedule
45 new homes with 35% affordable = 29 Market and 16 affordable.

Affordable mix indicated to accord with housing need survey and shown accordingly as
1 bed@5%, 2 bed@25%, 3 bed@55% and 4 bed@15%
Mix of tenure of affordable homes to be agreed with LPA

Market mix shown as 2 bed@30%, 3 bed@50%, 4/5 bed@20%

Affordable

Unit Name	Unit Ref	Bedrooms	Bedspaces	G.I.F.A sq/m	Number Off	Total sq/m
Symons (apt gf)	Sym (apt gf)	1	2	50.00	1	50.00
Symons (apt ff)	Sym (apt ff)	1	2	57.38	1	57.38
Tawney (bung)	Taw (bung)	2	4	70.37	2	140.74
Savage	Sav	2	4	79.00	2	158.00
Sassoon	Sas	3	5	93.02	7	651.14
Shol	Sho	3	5	93.02	1	93.02
Scurfield	Scu	4	6	106.00	2	212.00
					16	1362.28

Market

Unit Name	Unit Ref	Bedrooms	Bedspaces	G.I.F.A sq/m	Number Off	Total sq/m
Dekker	Dek	2	3	70.00	7	490.00
Lydford	Lyd	2	3	85.92	2	171.84
Holst	Hol	3	5	102.78	3	308.34
Latchford	Lat	3	6	129.34	13	1681.42
Gwynnr	Gwy	4	6	129.34	2	258.68
Beaufort	Bea	5	9	166.09	2	332.18
					29	3242.46

NB Law 3 bed repurposed as 2 bed + study

Parking excluding garages
1 bed = 1 x allocated space, 2/3 bed = 2 x allocated spaces, 4+ bed = 3 x allocated spaces
All garages (as indicated on plan) min 3.0x6.0m internally to allow for parking and cycle storage
Plots without garages to have secure shed or proprietary storage to LPA requirement

Scale bar 1:500

0 10 20 30 40 50

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- ☐ Construction issue
- ☐ As Built

Rev.	Description	Date
Rev. B	Footpaths updated to obtain necessary visibility spays.	16/03/23
Rev. A	Tandem parking updated to plot 3, 22 & 24. Visibility splay updated adjacent plot 37. Visitor spaces omitted and green space added. Turning spaces added & footpaths updated.	15/03/23

Drawing title:	Proposed Site Layout
Project:	Land at Breinton Lee, Hereford
Scale:	1:500 @ A1
Date:	July 2022
Client:	Cotswold Oak Ltd
Drawn by:	AH
Checked:	JE
Project & Drawing Nos.:	21.20.004 PL105

coombes : everitt architects limited
105-107
Bath Road
Cheltenham
Gloucestershire
GL53 7LE

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Chartered Practice

t: 01242 807727 f: 0845 5575833
e: info@ce-architects.co.uk
www.ce-architects.co.uk

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Appendix B – Topographical Survey

Survey Control Co-Ordinates

Name	Type	Easting(X)	Northing(Y)	Level(Z)
S001	Survey Nail	347258.385	241427.340	69.243
S002	Survey Nail	347257.382	241381.934	69.301
S003	Survey Nail	347253.316	241361.946	69.344

Grid Orientation: Ordnance Survey GPS Co-ordinates
Level Datum: Ordnance Survey GPS Datum

Drawing Notes

1. All dimensions are in Metres
2. Certain levels have been frozen on the "HTOMIT" Layer to prevent text overwriting
3. A qualified arboriculturalist should be consulted if tree species are crucial
4. Tree heights are approximate to the nearest metre
5. 3D drawing available on request

Survey Legend

AB	Air Brick
ACU	Air Conditioning Unit
AV	Air Valve
A/R	Assumed Route
BB	Belisha Beacon
BK/W	Brick Wall
BLK/W	Block Wall
BO	Bollard
BX	Box
BS	Bus Stop Sign
BT	British Telecom Cover
CA	Camera
CE	Cellar
CL	Cover Level
CF	City Fibre
CSU	Ceiling Slopes Up
DPC	Damp Proof Course
DR	Drain
DH	Door Height
ER	Earth Rod
EC	Electricity Cover
EP	Electricity Pole
FH	Fire Hydrant
FL	Flood Light
FW	Foul Water
GA	Gas Valve
GU	Gully
HTOP	Top of Hedge Height
IC	Inspection Cover
IL	Invert Level
KI	Kerb Inlet
LP	Lamp Post
MB	Multibole/Stem Tree
MH	Manhole
MK	Marker Post
MO	Mooring
NPV	No Pipe Visible
NSV	No Service Visible
PB	Post Box
PO	Post
PM	Parking Meter
PS	Private Sign
RE	Rodding Eye
RP	Reflector Post
RS	Road Sign
RWP	Rainwater Pipe
SO	Soffit Level
SP	Sign Post
ST	Stop Tap
ST/W	Stone Wall
SV	Stop Valve
SVP	Soil Vent Pipe
SW	Surface Water
TB	Telephone Box
TH	Threshold Level
TM	Telephone Mast
TOB	Top of Beam
TP	Telegraph Pole
TL	Traffic Light
TV	Cable TV Cover
WL	Water Level
WM	Water Meter
WO	Wash Out
UTL	Unable To Lift
USB	Underside of Beam

Building
Building Ridge — Rxx.xx
Building Eaves — Exx.xx
Drainage Ditch/Cover
Embankment Top
Embankment Bottom
Fence
Gate
Kerb
Kerb Top
Dropped Kerb
Door Opening
Major Contours (0.5m) — ht
Minor Contours (0.25m)
Canopy/Overhang
Overhead Electric Line — OHE
Overhead Telecom Line — OHT
Service Cover
Street Furniture
Surface Change
Vegetation
Walls/Columns
Top of Wall (TOW)
Waterline
C=Cill level
H=Head level — Windows

Girth/Spread
Species
Height — Tree
Sapling
Shrub
Bush
Hedge

Survey Control Station
Station Level — 50.000

Fence Abbreviations

BWF	Barb Wire
CBF	Close Board
CLF	Chain Link
IRF	Iron Railings
PAF	Palisade
PCF	Post & Chain
PRF	Post & Rail
PWF	Post & Wire
WPF	Wooden Panel

Precise Land Surveys Limited
Land & Measured Building Surveyors

30 Hall Green
Malvern
Worcestershire
WR14 3QX

Tel: 01684 259952
E-Mail: info@preciselandsurveys.co.uk
Web: www.preciselandsurveys.co.uk

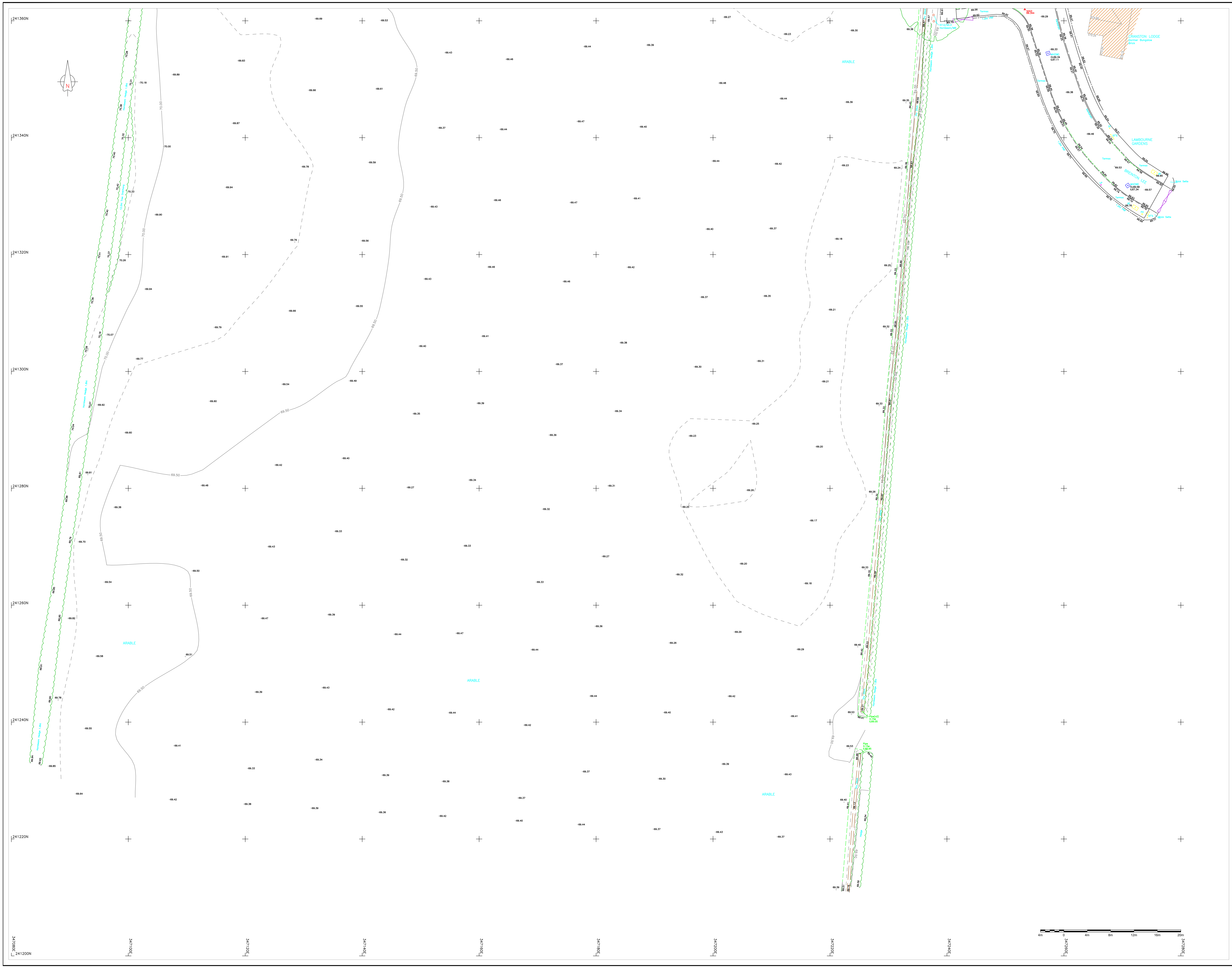
Drawing No.	Date	Scale	Sheet Size	Revision
PLS452_S1	JUN 21	1:200	A0	–

Drawing Title

TOPOGRAPHICAL SURVEY

Project

LAND AT BREINTON LEE, KINGS ACRE ROAD, HEREFORD



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FL	Flood Light
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IC	Inspection Cover
IL	Invert Level
KI	Kerb Inlet
LP	Lamp Post
MB	Multibole/Stem Tree
MH	Manhole
MK	Marker Post
MO	Mooring
NPV	No Pipe Visible
NSV	No Service Visible
PB	Post Box
PO	Post
PM	Parking Meter
PS	Private Sign
RE	Rodding Eye
RP	Reflector Post
RS	Road Sign
RWP	Rainwater Pipe
SO	Soffit Level
SP	Sign Post
ST	Stop Tap
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TL	Traffic Light
TV	Cable TV Cover
WL	Water Level
WM	Water Meter
WO	Wash Out
UTL	Unable To Lift
USB	Underside of Beam

Building
Building Ridge Rxx.xx
Building Eaves Exx.xx
Drainage Ditch/Cover
Embankment Top
Embankment Bottom
Fence
Gate
Kerb
Kerb Top
Dropped Kerb
Door Opening
Major Contours (0.5m) ht
Minor Contours (0.25m)
Canopy/Overhang
Overhead Electric Line OHE
Overhead Telecom Line OHT
Service Cover
Street Furniture
Surface Change
Vegetation
Walls/Columns
Top of Wall (TOW)
Waterline
C=Cill level
H=Head level
Windows

Girth/Spread
Species
Height
Tree

Sapling
Shrub
Bush
Hedge

Survey Control Station
Station Level
50.000

Fence Abbreviations

BWF	Barb Wire
CBF	Close Board
CLF	Chain Link
IRF	Iron Railings
PAF	Palisade
PCF	Post & Chain
PRF	Post & Rail
PWF	Post & Wire
WPF	Wooden Panel

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Tel: 01684 259952
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Revision –

Drawing No.	Date	Scale	Sheet Size
PLS452_S2	JUN 21	1:200	A0

Drawing Title

TOPOGRAPHICAL SURVEY

Project

LAND AT BREINTON LEE, KINGS ACRE ROAD, HEREFORD

coombes : everitt architects limited
105-107
Bath Road
Cheltenham
Gloucestershire
GL53 7LE

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NORTH

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Drawing title:	Topographical Site Survey, sheet 1 of 2	Project:	Land at Breinton Lee, Hereford
Client:	Cotswold Oak Ltd	Scale:	1:250 @ A1
Drawn by:	AH Checked: JE	Date:	July 2022
Project No:	21.20.004	Project / Drawing No:	21.20.004 PL102

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coombes : everitt architects limited
105-107
Bath Road
Cheltenham
Gloucestershire
GL53 7LE

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Draft Planning

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Client:	Cotswold Oak Ltd	Scale:	1:250 @ A1
Drawn by:	AH Checked: JE	Date:	July 2022
Project No:	21.20.004	Project / Drawing No:	21.20.004 PL103

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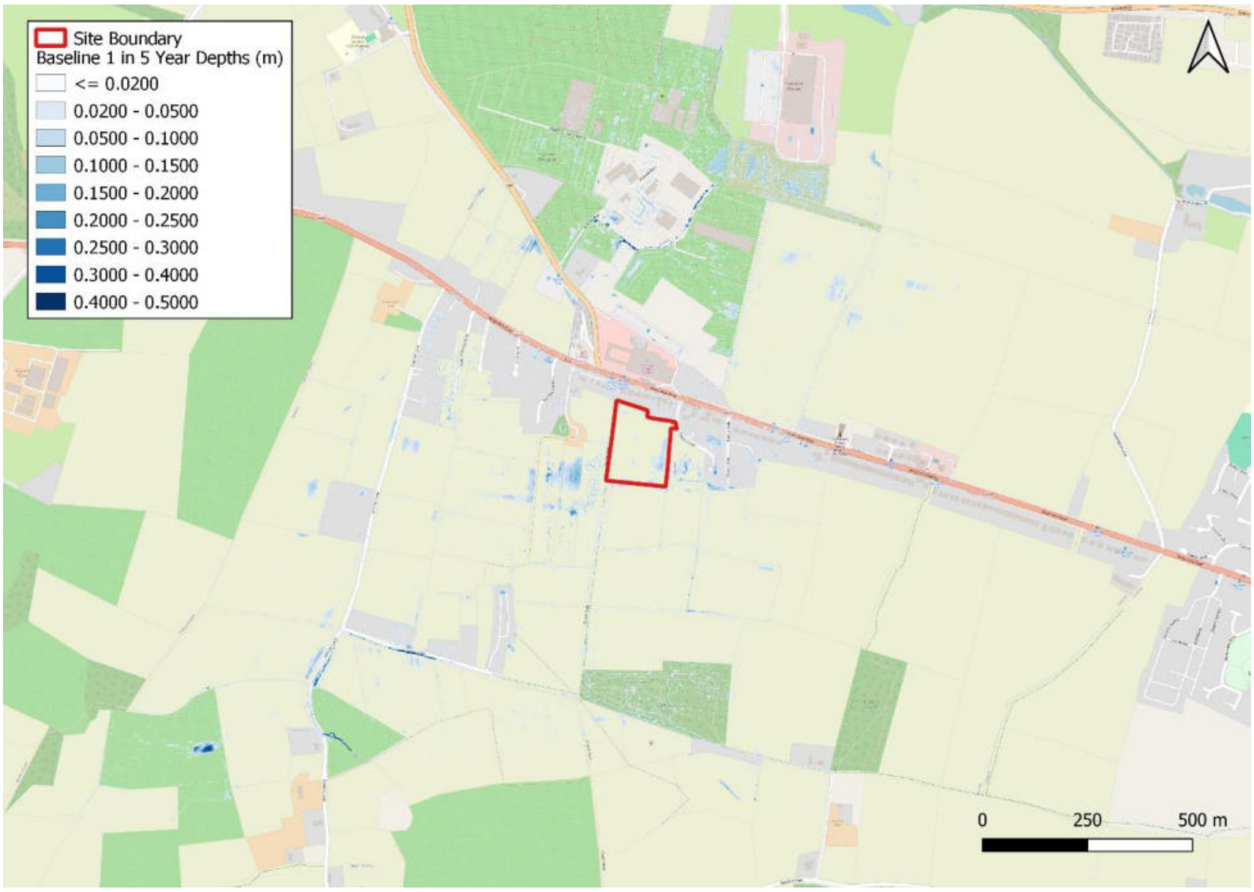
Appendix C – Modelled Flood Extents and Depths Across the Site and Catchment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0.4000 - 0.5000
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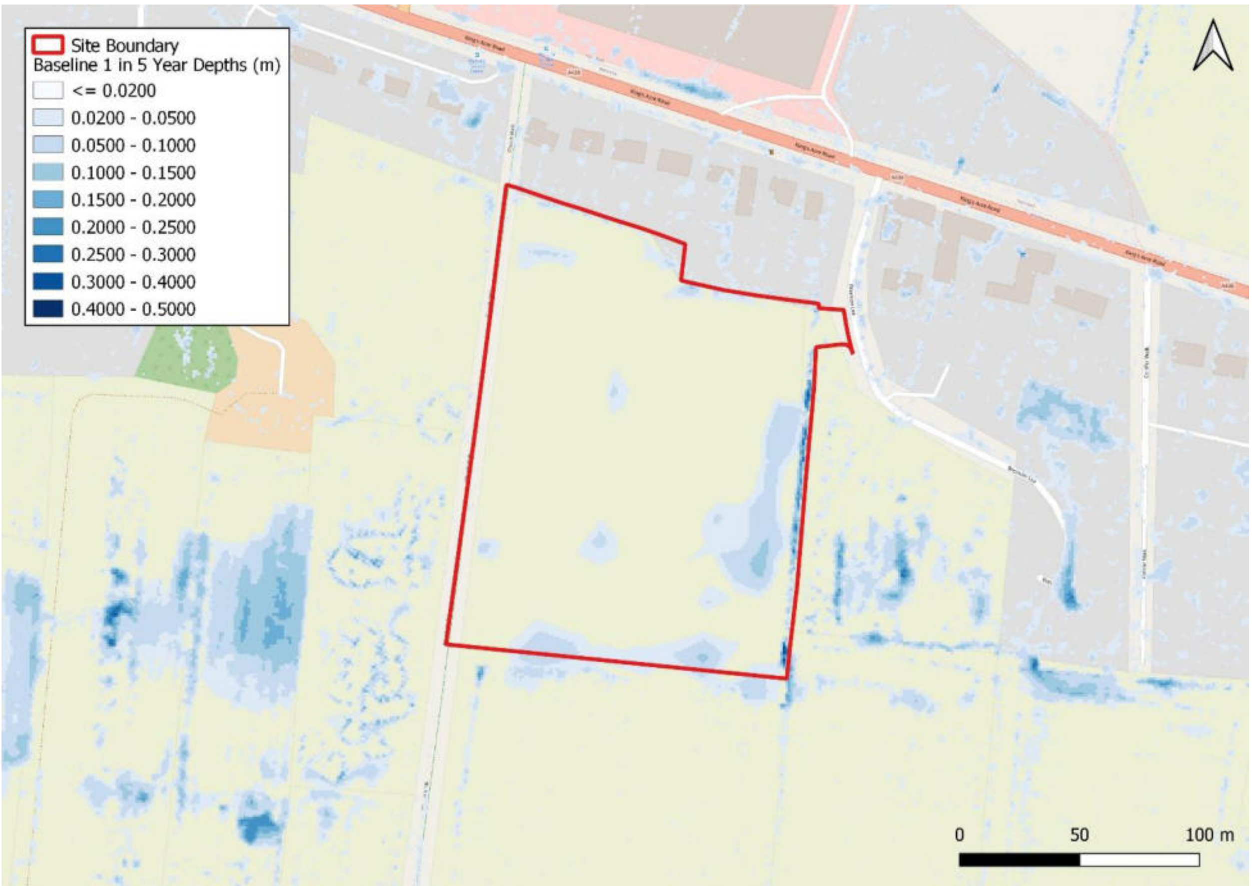
500 m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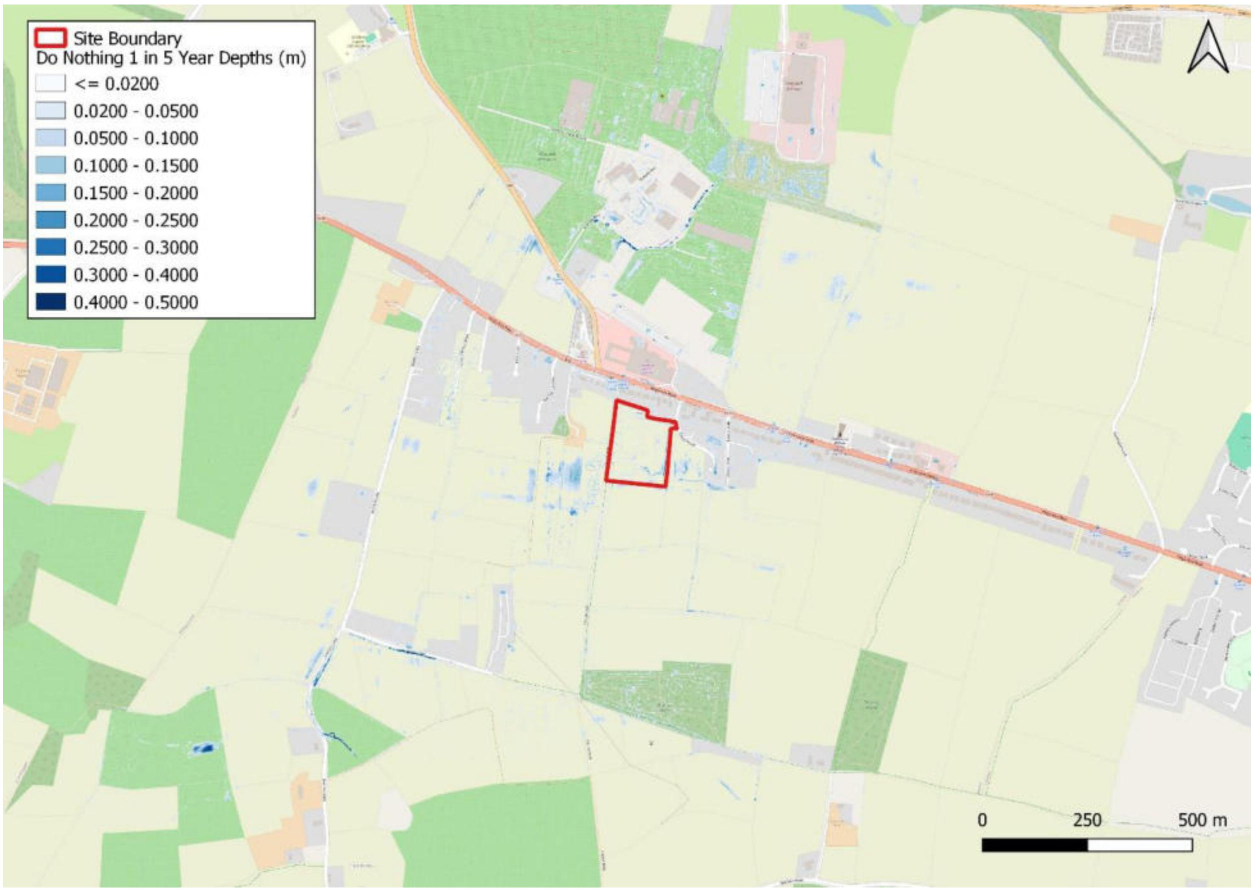
0
50
100 m



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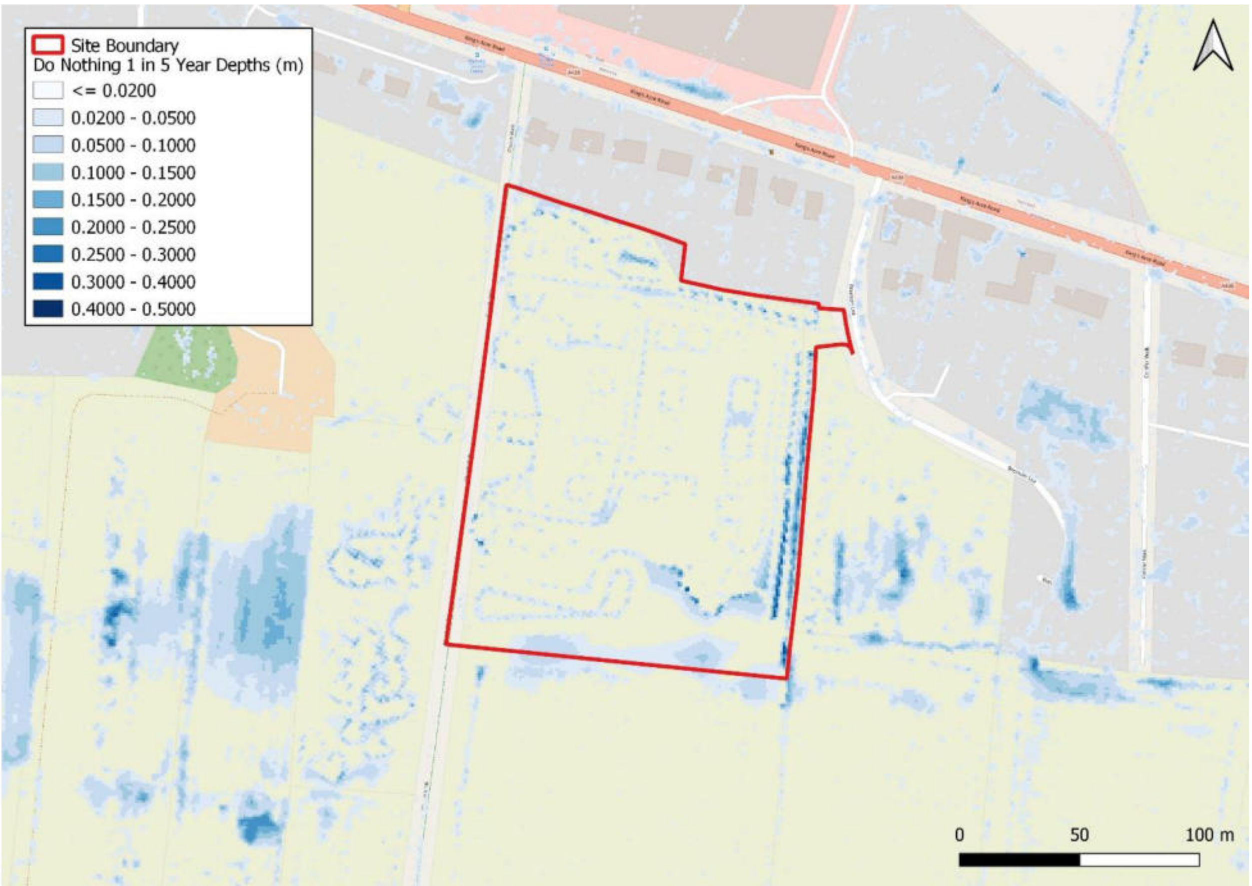
0.4000 - 0.5000
0
250
500 m



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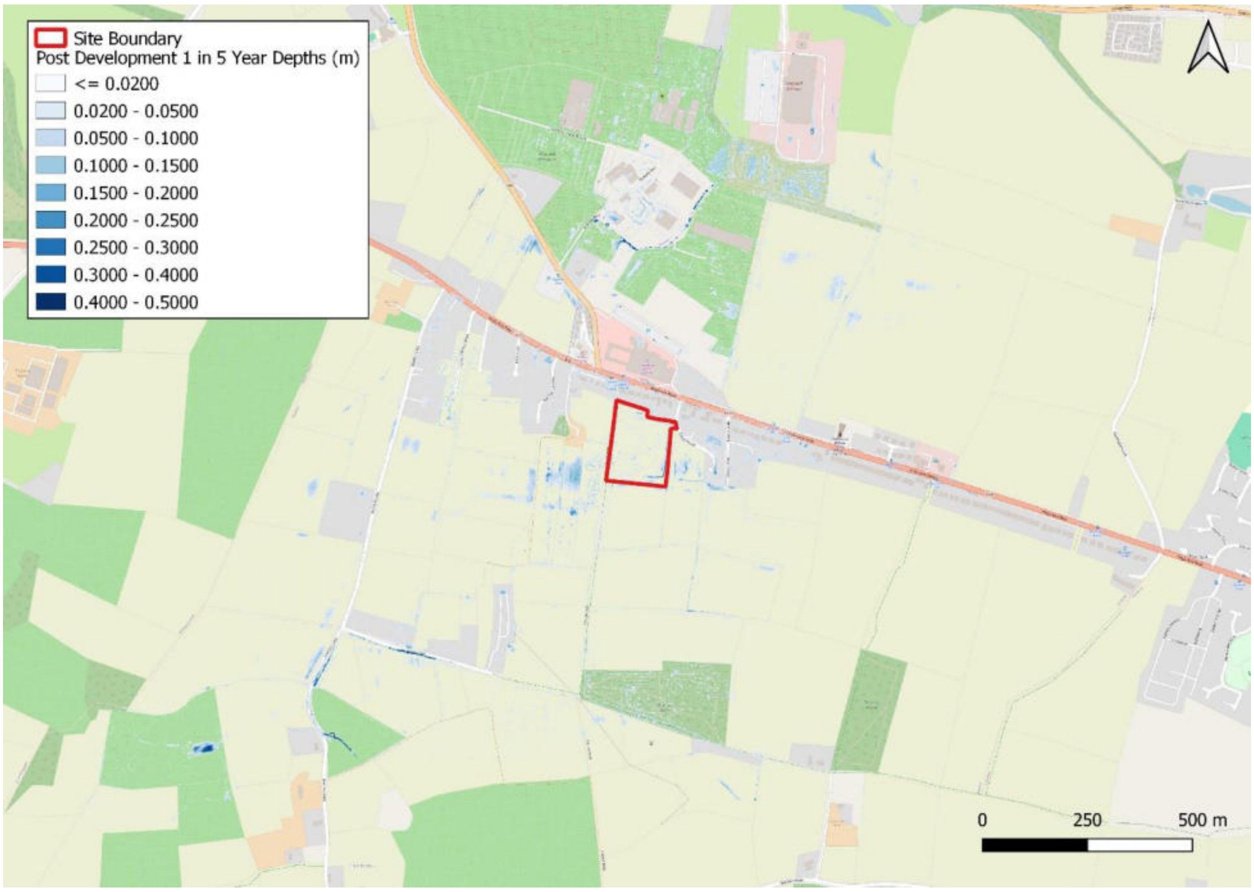
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m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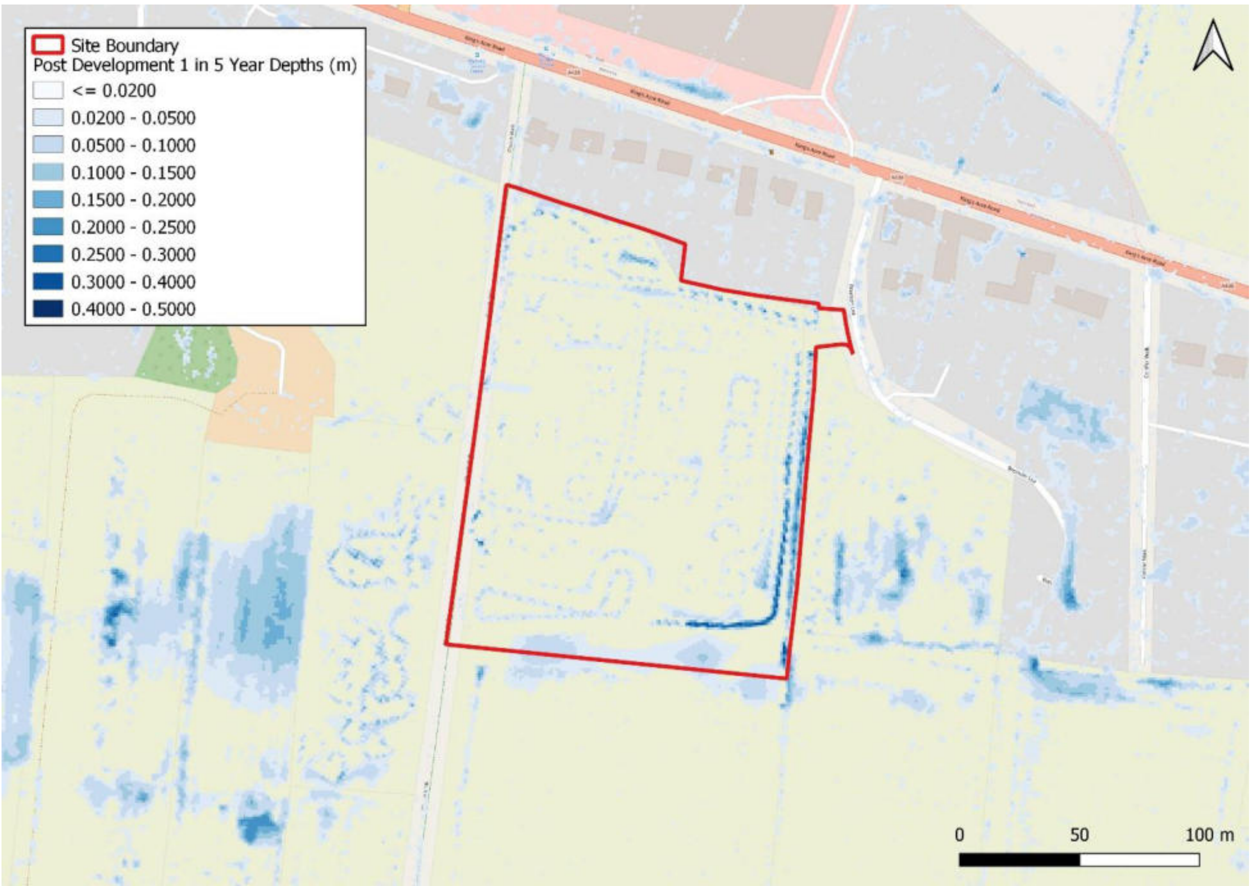
0.4000 - 0.5000
0
250
500 m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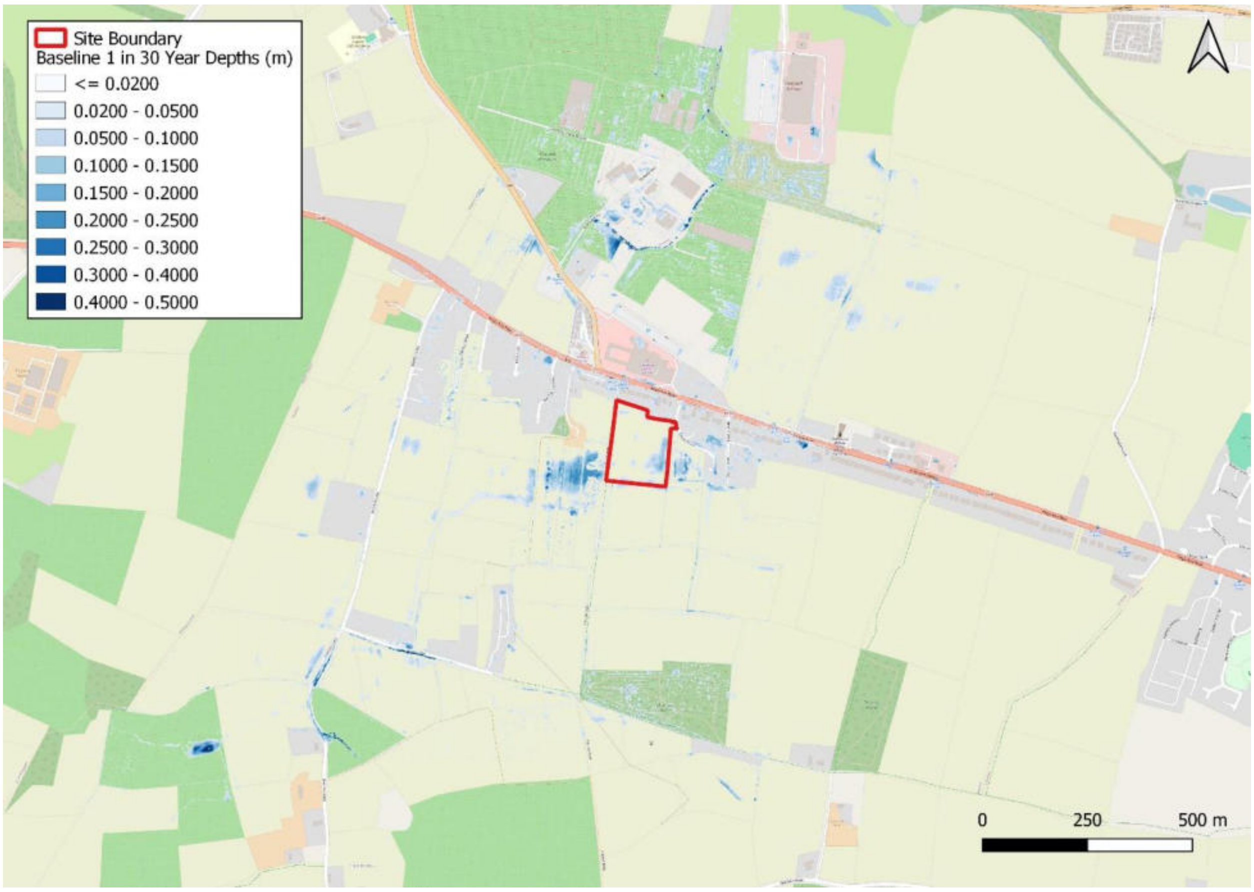
0.4000 - 0.5000
0
50
100 m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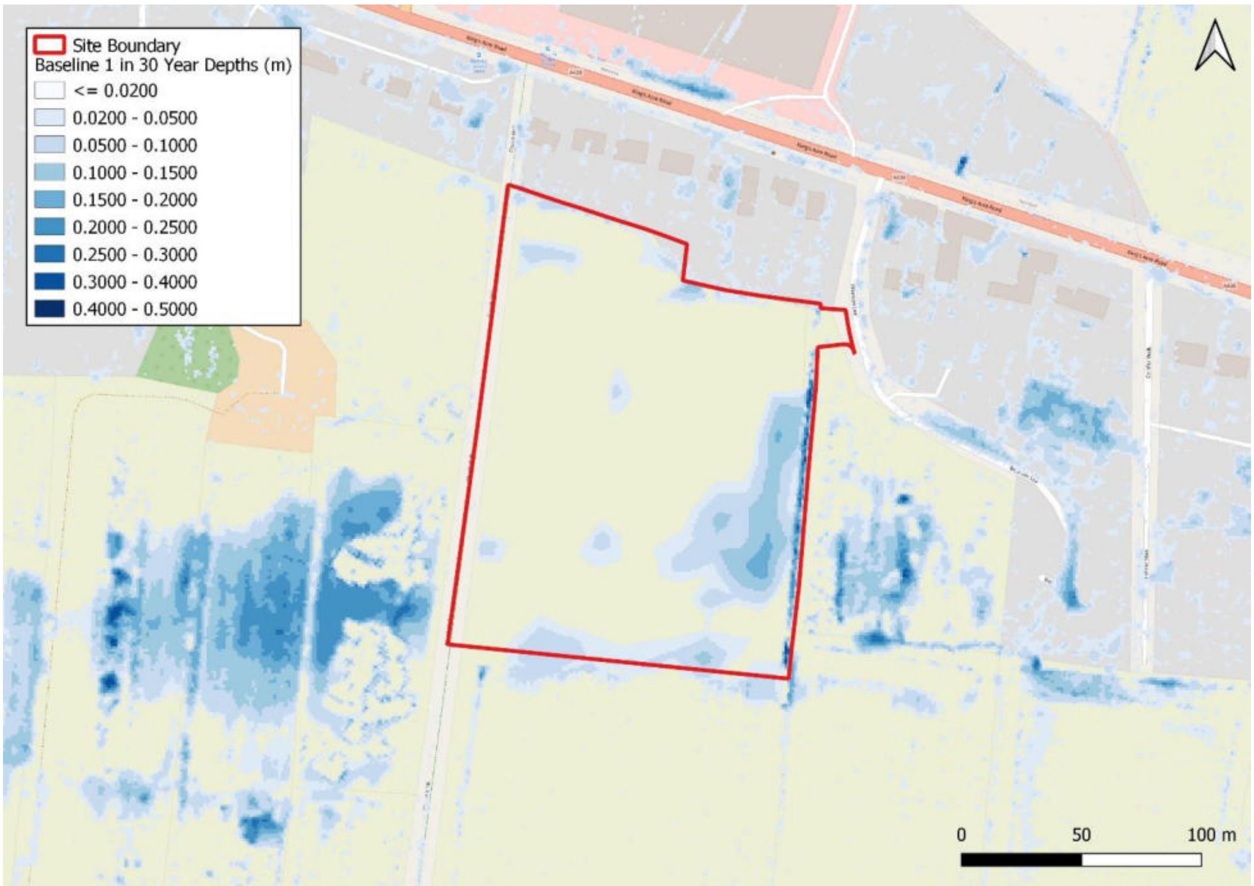
0.4000 - 0.5000
0
250
500 m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0.3000 - 0.4000
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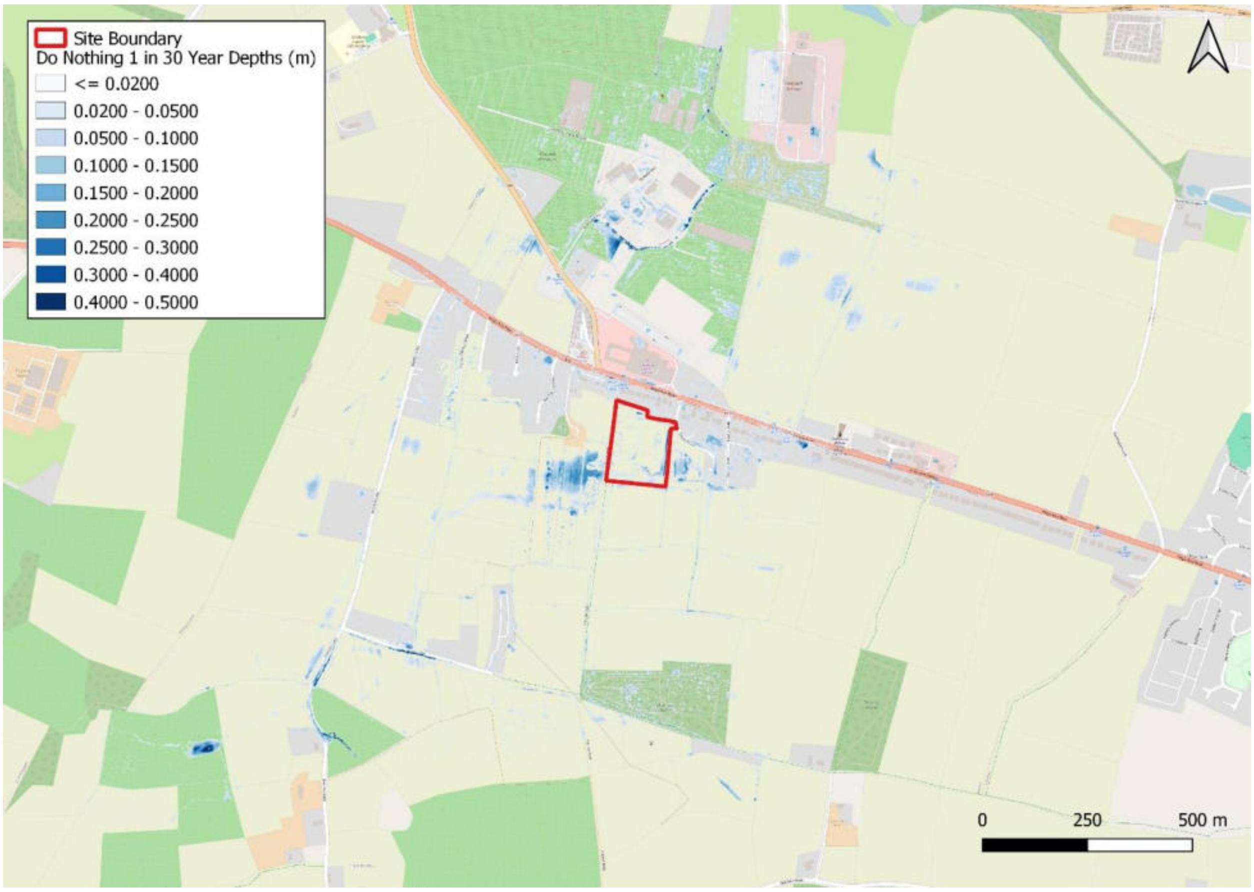
0
50
100 m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<= 0.0200
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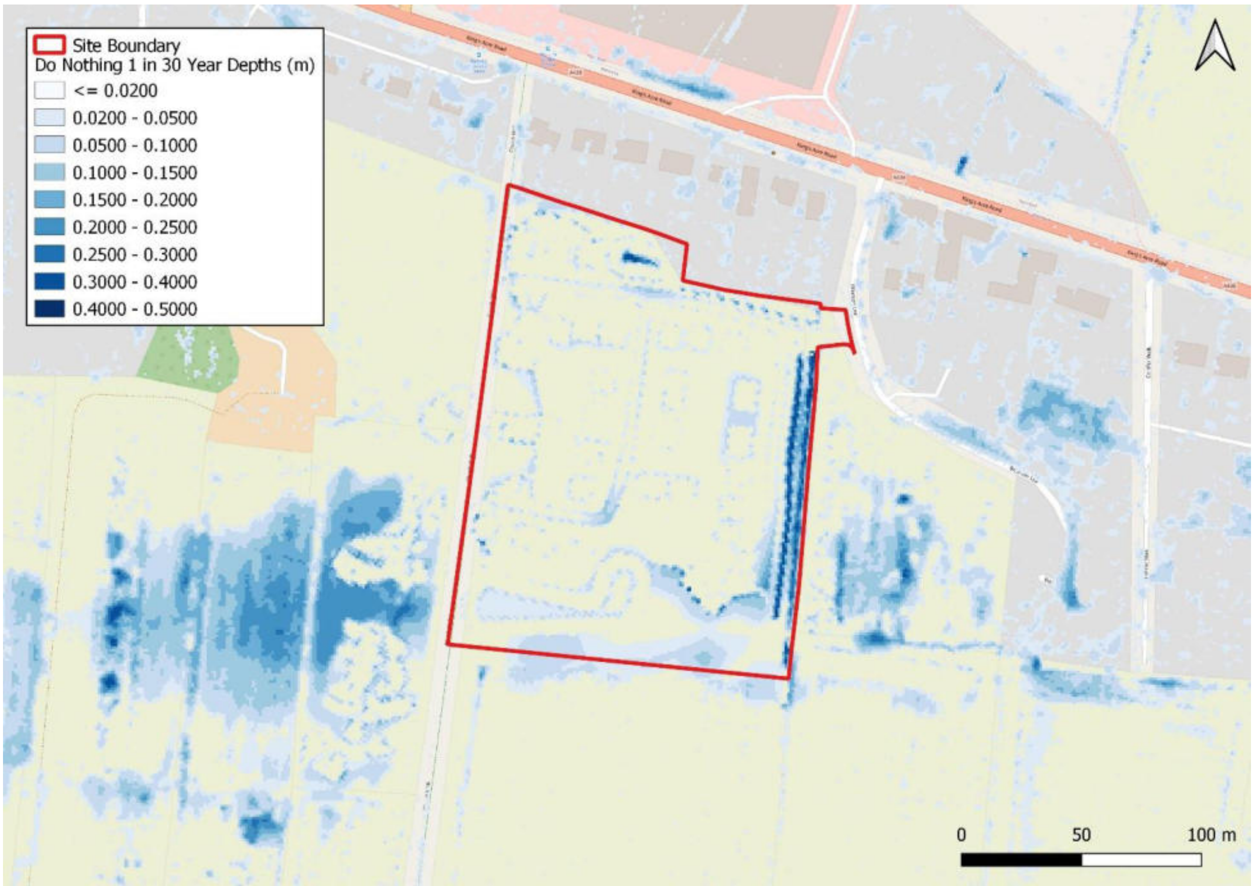
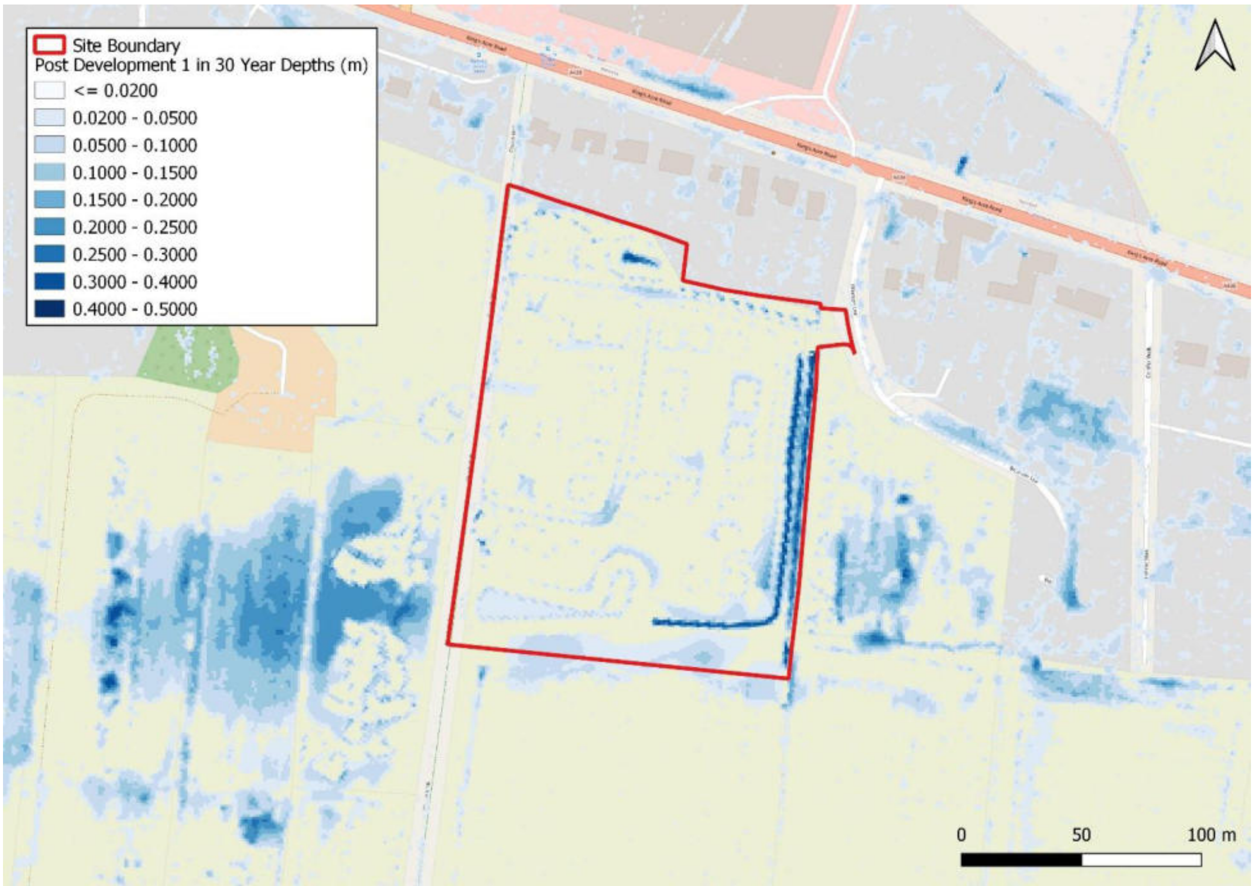
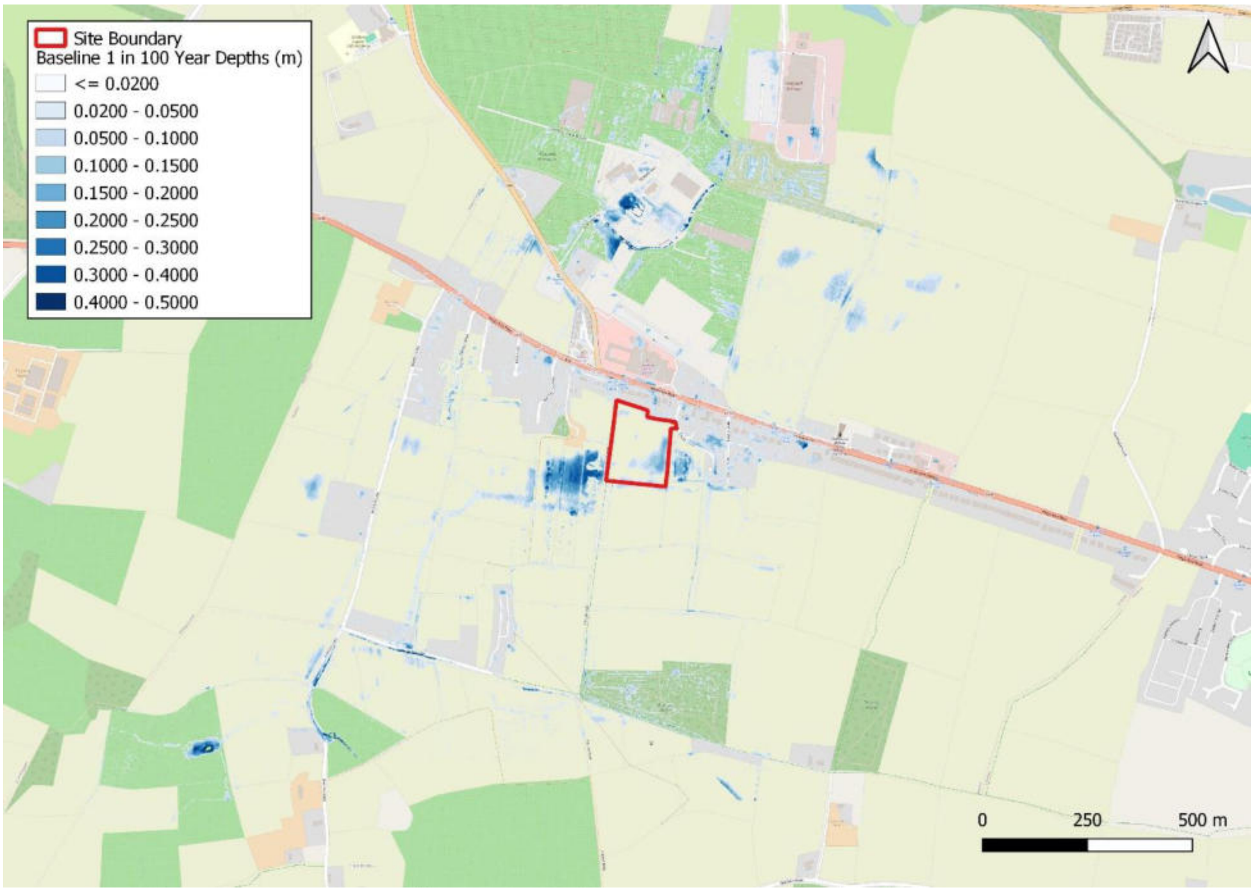
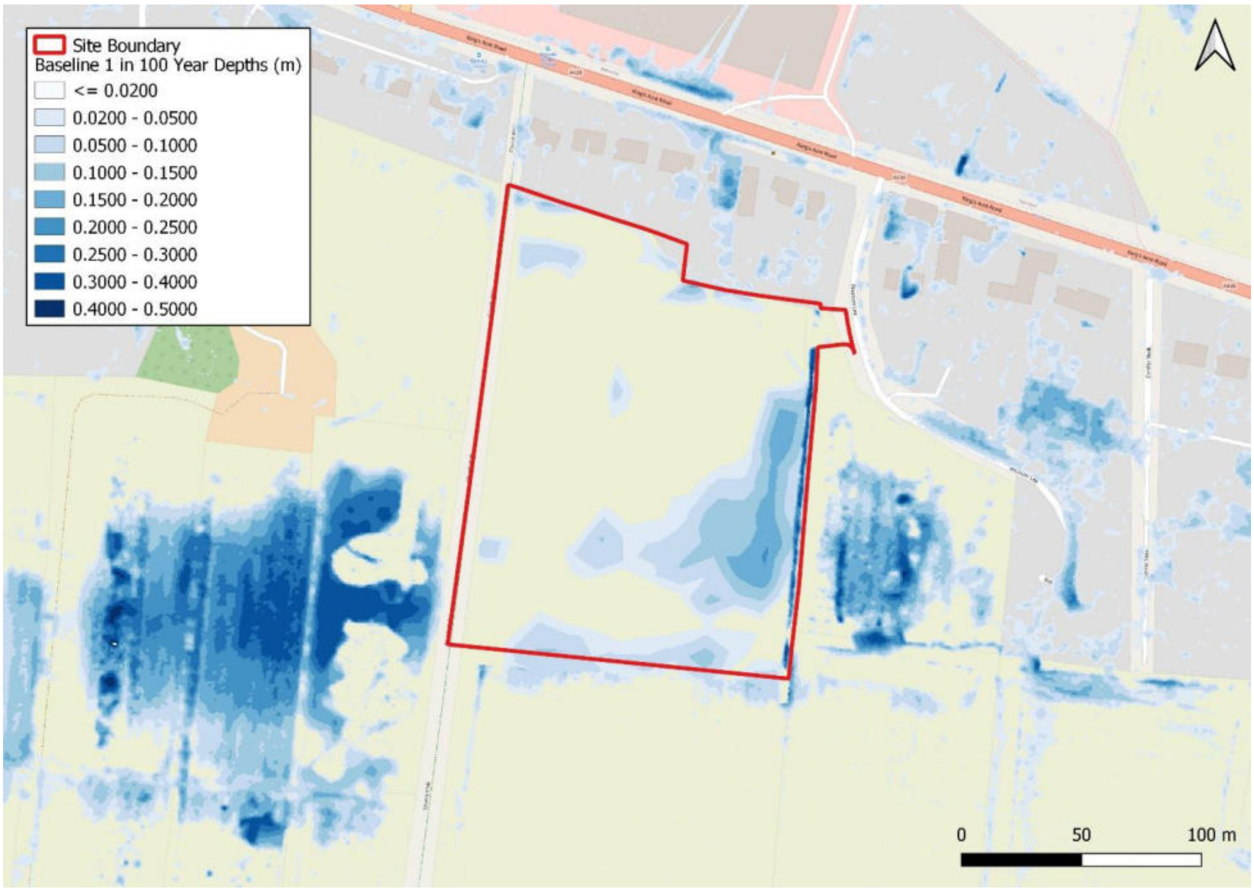
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m

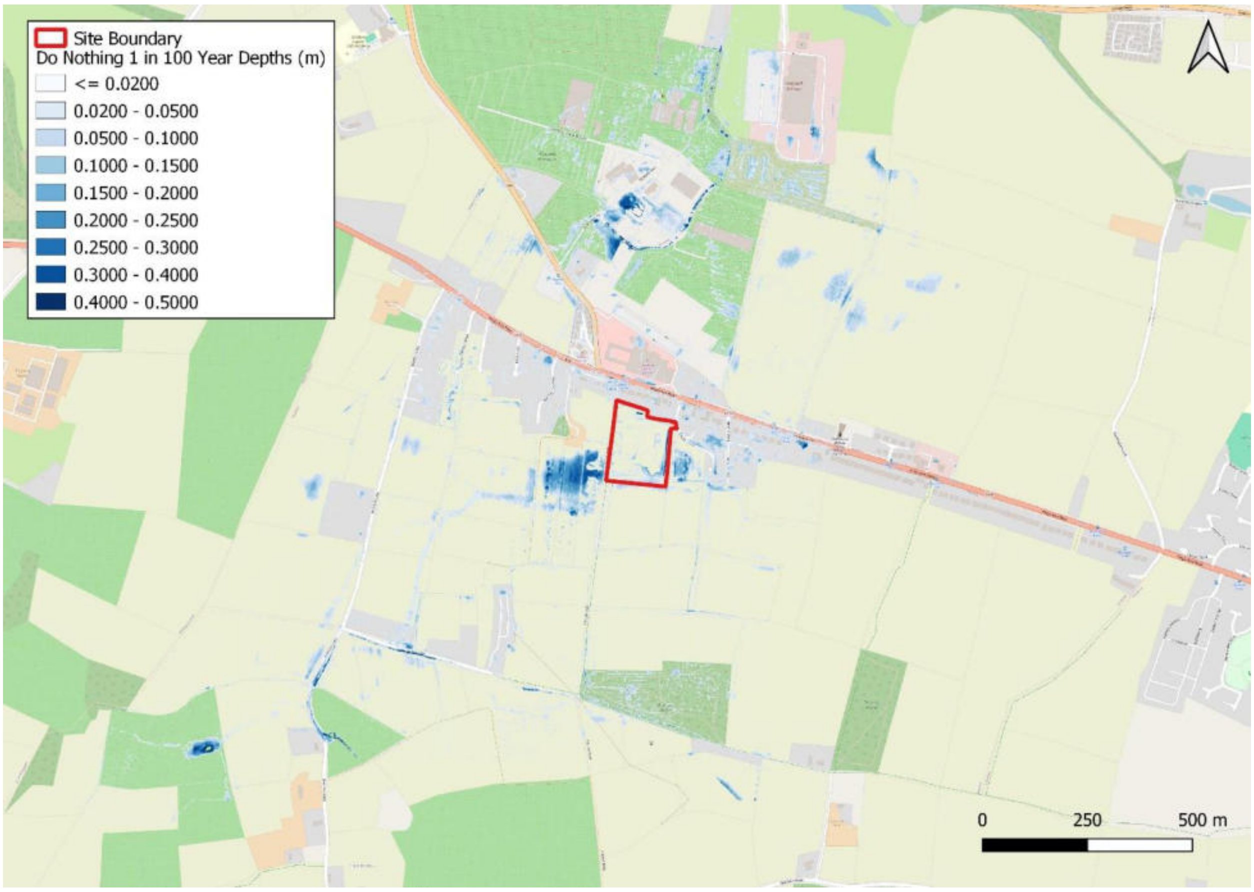

Site Boundary
Do Nothing 1 in 30 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m

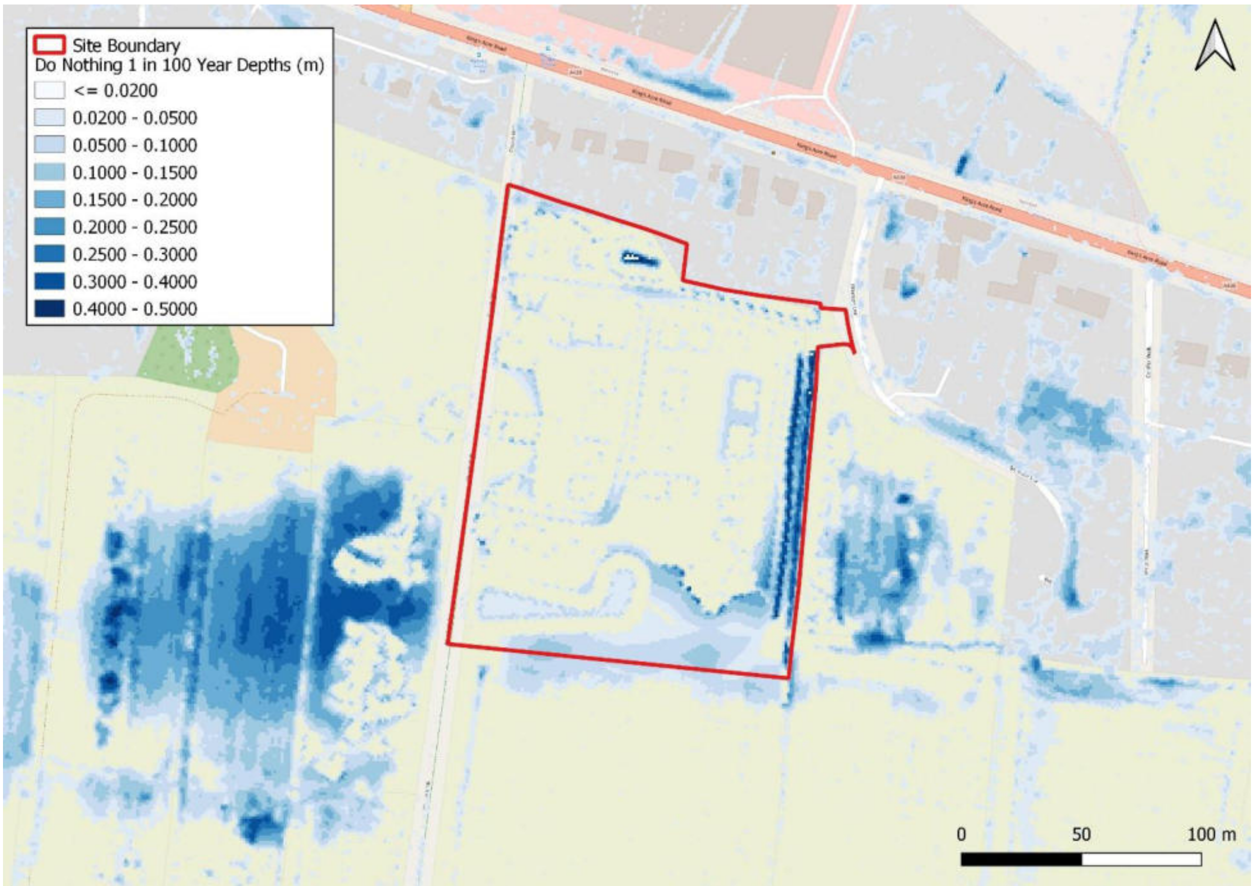

Site Boundary
Post Development 1 in 30 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m

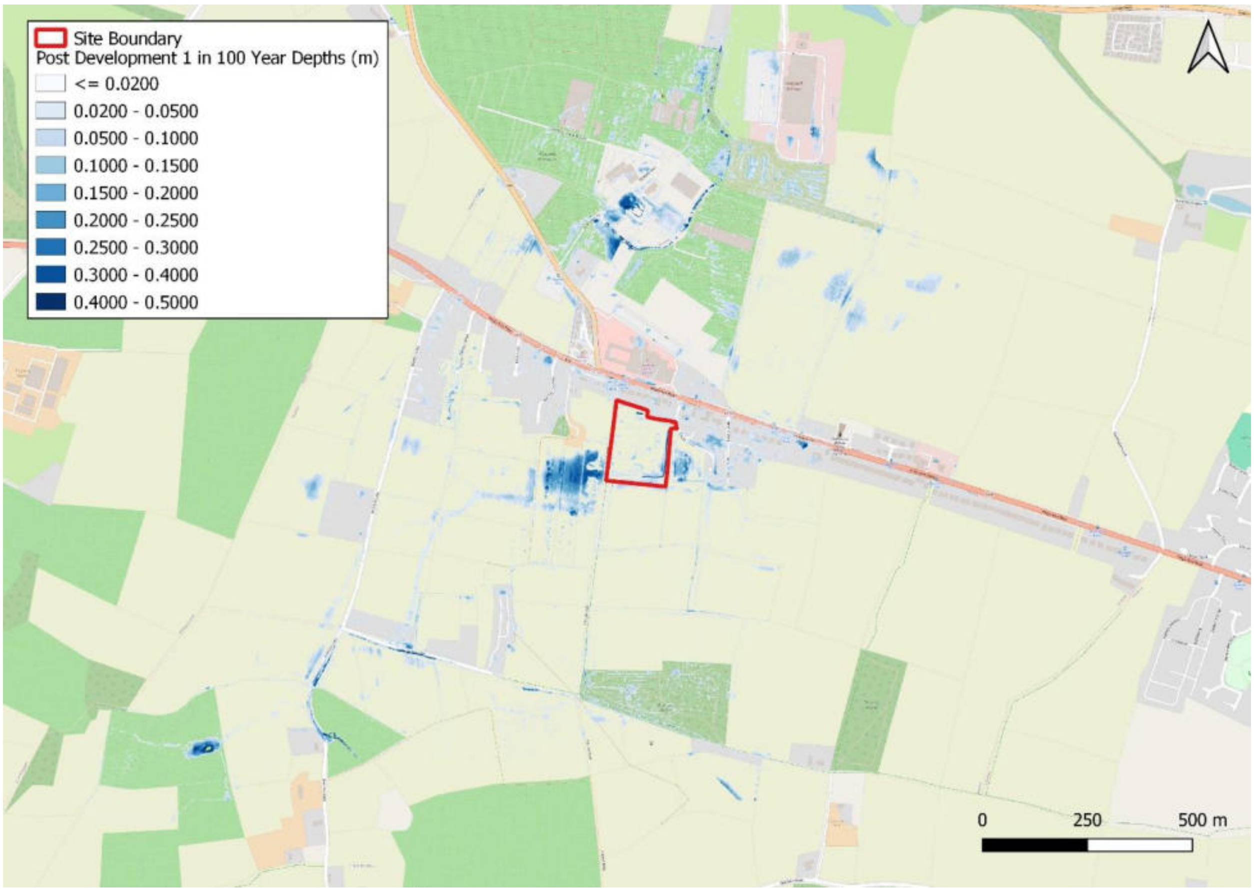

Site Boundary
Post Development 1 in 30 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m

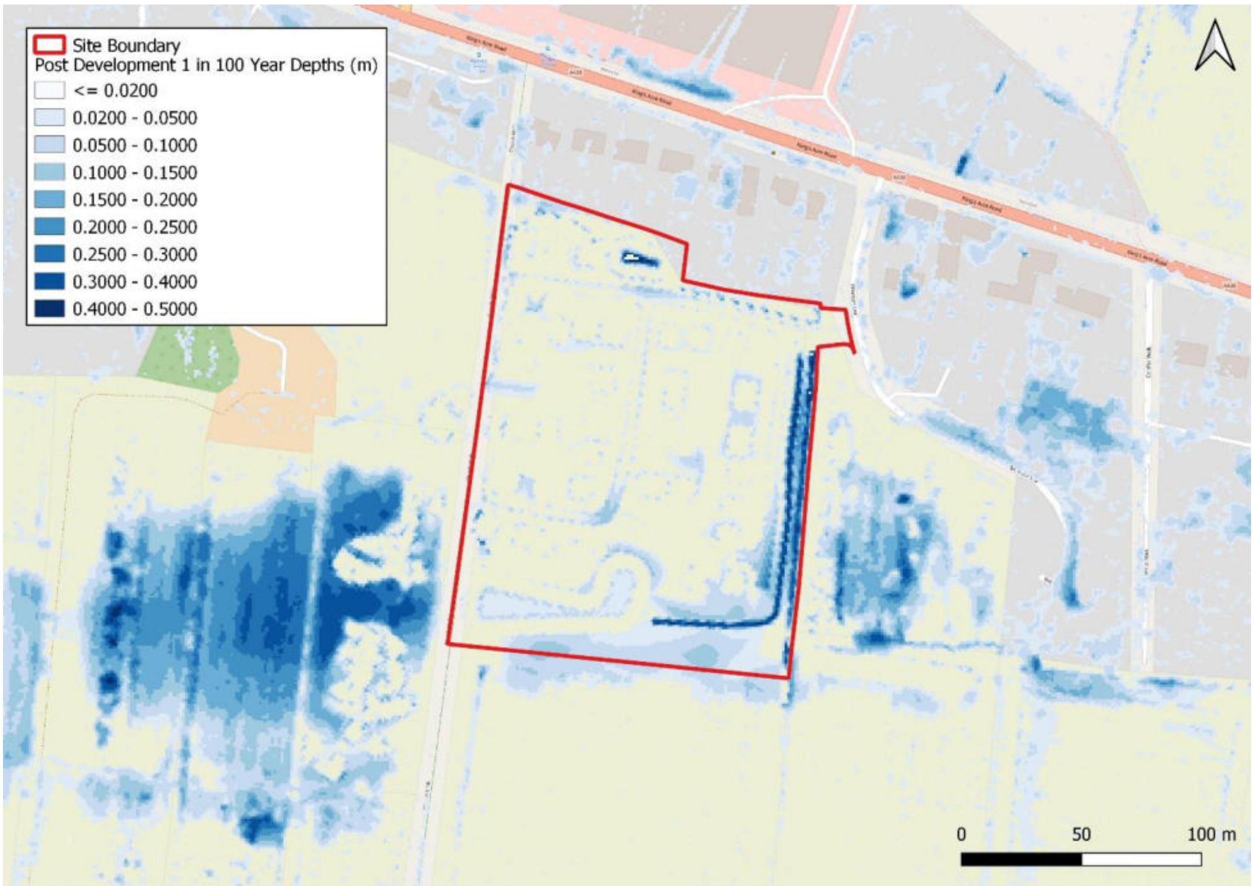

Site Boundary
Baseline 1 in 100 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m

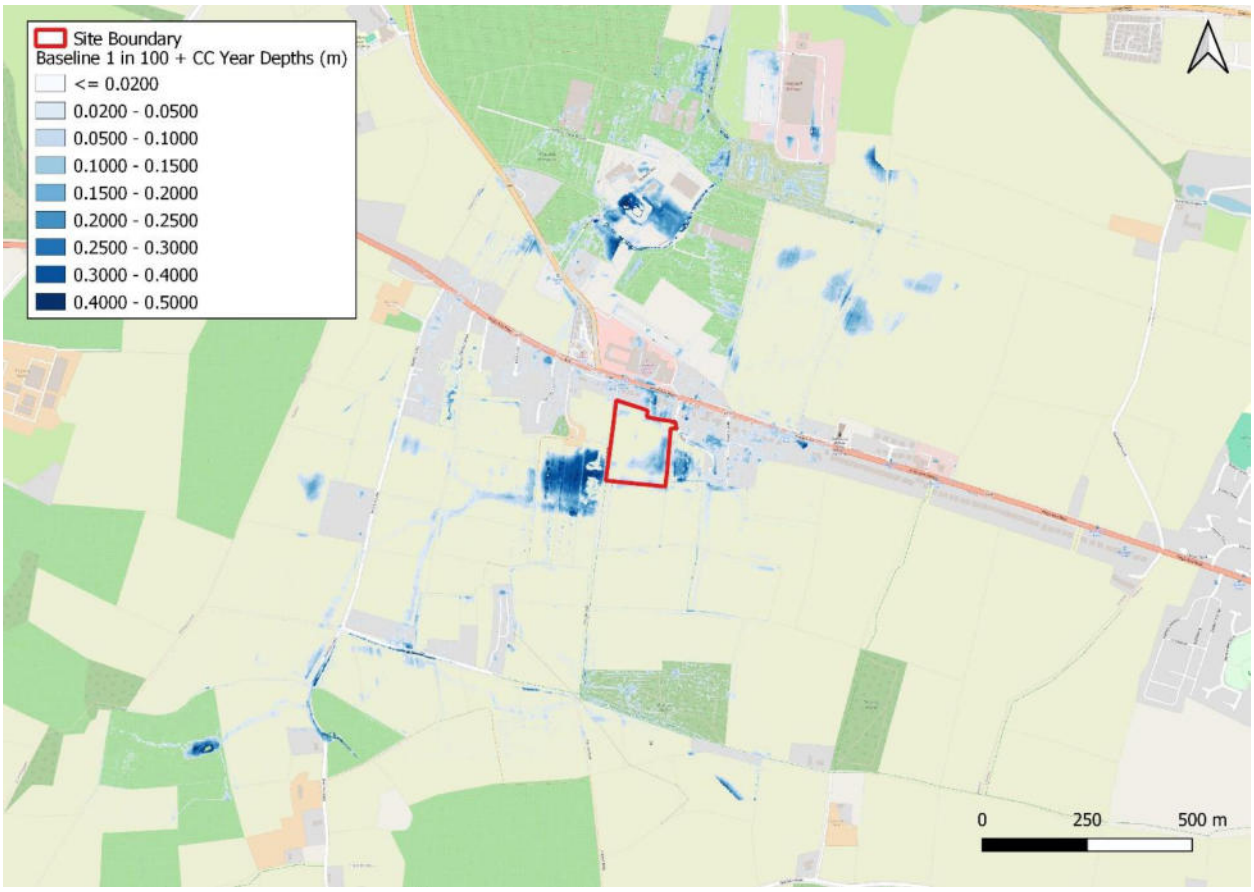

Site Boundary
Baseline 1 in 100 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m

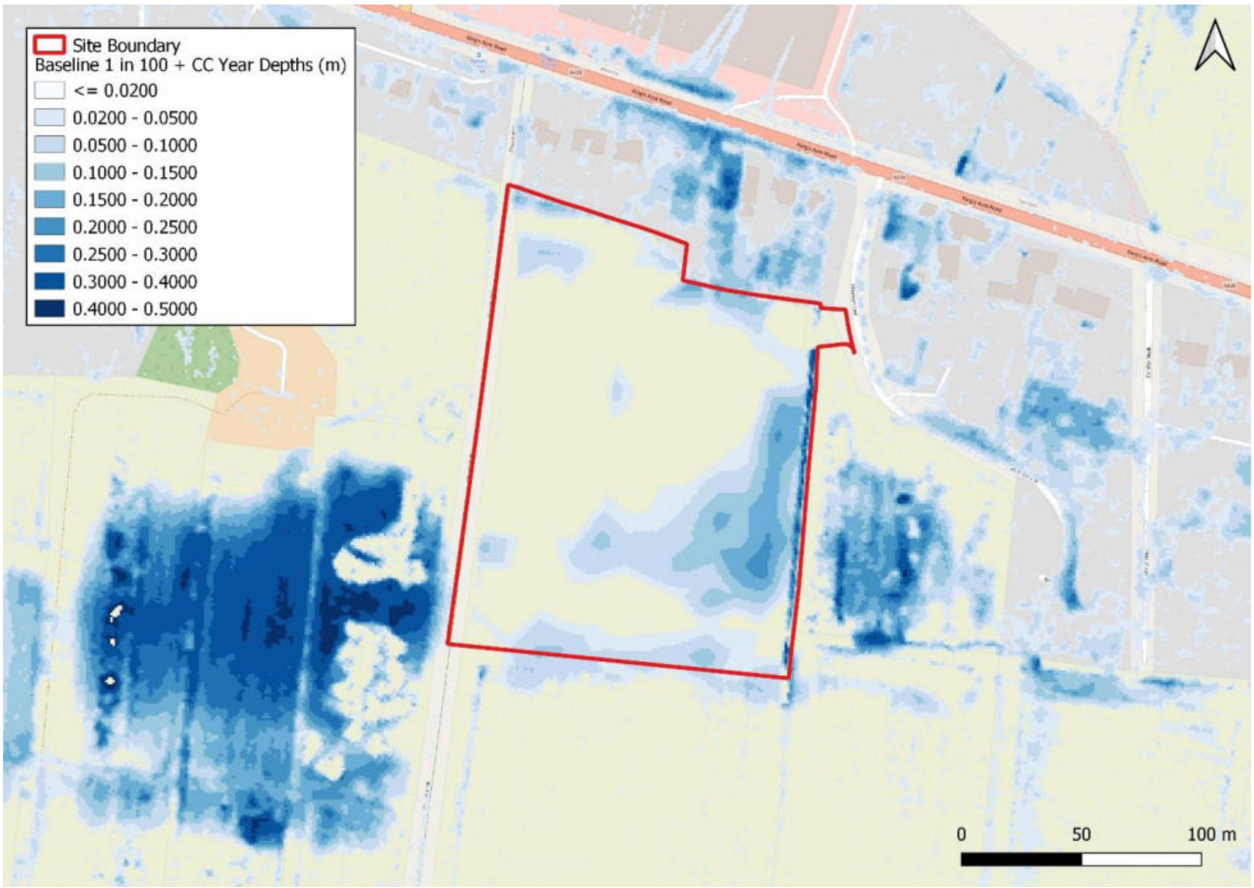

Site Boundary
Do Nothing 1 in 100 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m


Site Boundary
Do Nothing 1 in 100 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m


Site Boundary
Post Development 1 in 100 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m

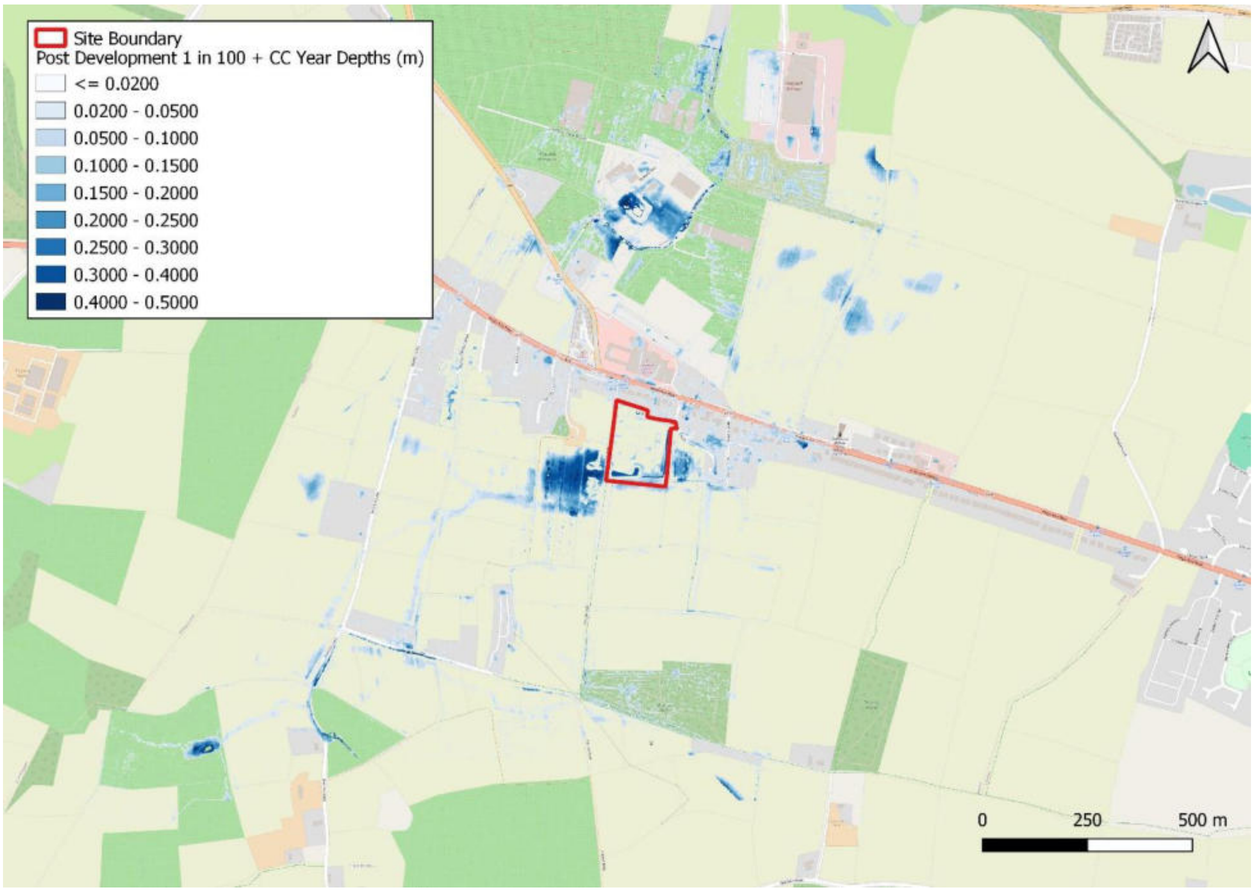

Site Boundary
Post Development 1 in 100 Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m


Site Boundary
Baseline 1 in 100 + CC Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m

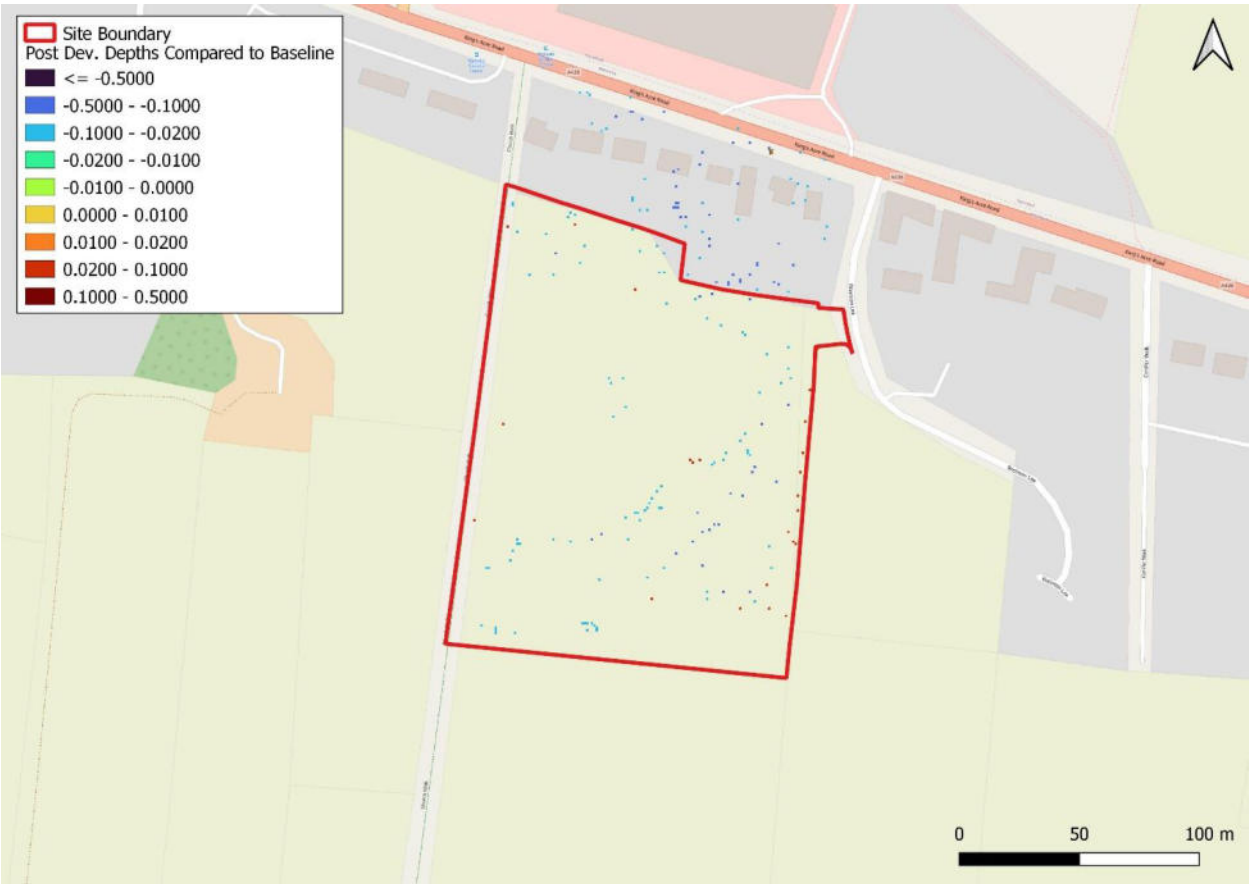

Site Boundary
Baseline 1 in 100 + CC Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m

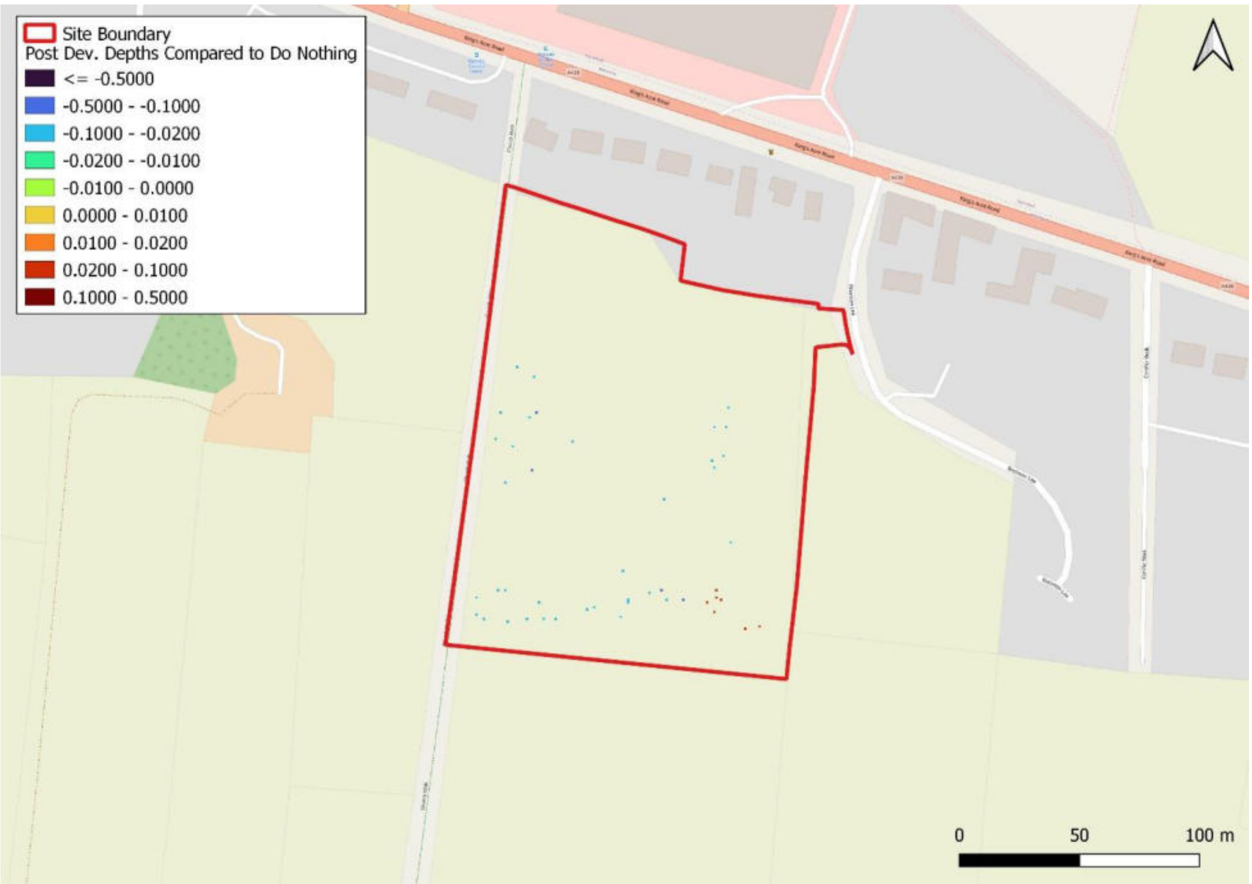

Site Boundary
Do Nothing 1 in 100 + CC Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m


Site Boundary
Do Nothing 1 in 100 + CC Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m


Site Boundary
Post Development 1 in 100 + CC Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
250
500 m


Site Boundary
Post Development 1 in 100 + CC Year Depths (m)
<= 0.0200
0.0200 - 0.0500
0.0500 - 0.1000
0.1000 - 0.1500
0.1500 - 0.2000
0.2000 - 0.2500
0.2500 - 0.3000
0.3000 - 0.4000
0.4000 - 0.5000
0
50
100 m


Site Boundary
Post Dev. Depths Compared to Baseline
<= -0.5000
-0.5000 - -0.1000
-0.1000 - -0.0200
-0.0200 - -0.0100
-0.0100 - 0.0000
0.0000 - 0.0100
0.0100 - 0.0200
0.0200 - 0.1000
0.1000 - 0.5000
0
50
100 m


Site Boundary
Post Dev. Depths Compared to Do Nothing
<= -0.5000
-0.5000 - -0.1000
-0.1000 - -0.0200
-0.0200 - -0.0100
-0.0100 - 0.0000
0.0000 - 0.0100
0.0100 - 0.0200
0.0200 - 0.1000
0.1000 - 0.5000
0
50
100 m

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