Anglia Square, Norwich
Flood Risk Assessment: Modeling Report

Dated March 2022

Weston Homes

REPORT

Anglia Square Norwich Modelling Study

Modelling Report

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Table of Contents

Table of Tables

Table of Figures

Appendices

Glossary and Acronyms

Term	Definition
AEP	Annual Exceedance Probability is the probability of a rainfall or tidal event occurring within any one year. For example an event of a 100 year return period has an AEP of 1:100 or 1%.
Courant Number	A function of the amount of fluid that crosses the cell in a given time-step. For 2d modelling the Courant Number generally needs to be less than 10 and typically around 5 or less for real-world applications.
Critical Storm Duration	The duration of a specific storm event which creates the largest volume or highest rate of net storm water runoff for typical durations up to and including the 10 day duration event.
DDF	Depth Duration Frequency depths define the predicted total rainfall depth for a specific return period and storm duration.
DTM	Digital Terrain Model (also known as Digital Elevation Model) is a format for describing the topography of a terrain in a digital format. Often a digital terrain is formatted into a regular grid.
ESTRY	Dynamic flow program suitable for mathematic modelling floods and tides (and/or surges) in a virtually unlimited number of combinations.
Flood Defences	Artificial structures maintained to a set operational level designed to protect land people and property from Tidal and Fluvial flood sources to an established AEP threshold.
FEH	Flood Estimation Handbook
ReFH2	Second Revitalised Flood Estimation Handbook
Flood Source: Fluvial	When flows within watercourses exceed the capacity of the watercourse causing out of bank flows.
Flood Source: Pluvial	When rainfall causes overland flows which exceed the capacity of the drainage network, causing flooding to land that is normally dry.
Flood Source: Tidal	When high tide events overtop the shoreline to cause flooding to land behind.
Flood Zone 1	Low Probability. Land defined as having a less than 1:1000 AEP of flooding from tidal and fluvial sources.
Flood Zone 2	Medium Probability. Land defined as having a risk of fluvial flooding between 1:100 AEP and 1:1000 AEP. Or Land defined as having a risk of tidal flooding between 1:200 AEP and 1:1000 AEP.
Flood Zone 3 (A)	High Probability. Land defined as having a fluvial risk of 1:100 AEP or greater. Or a tidal risk of 1:200 AEP or greater.
Flood Zone 3 (B)	Functional Floodplain. Defined by SFRA's as areas where floodwater is stored during lower AEP events, typically the 1:20 AEP.
Flood Zone Map	The Environment Agency has produced a mapping data set which covers England and provides the general extents of Flood Zones 1, 2, and 3. However the national data set available online does not differentiate between Flood Zone 3 (A) and 3 (B)
LiDAR	Light Detection And Ranging is an accurate ground terrain model obtained by aerial survey. The typical vertical accuracy is +/- 150 mm, the horizontal spacing of survey points (resolution) is normally 0.5m in city centres, 1m in urban areas and 2m in rural areas.
Main River	Defined on the Main River map and relate to rivers on which the Environment Agency have powers to carry out flood defence works
Model Event	The Model Event is the AEP storm or flow profile used within each Model Scenario
MHWS	Mean High Water Springs – the mean high water level for spring tides
Model Scenario	Each Model Scenarios considers a range of Model Events to assess the impact of the Scenario, typical Model Scenarios are; base case, post development, post mitigation.
m AOD	Metres Above Ordnance Datum
OS	Ordnance Survey.
Ordinary Watercourse	A watercourse which does not form part of a Main River

Term	Definition
PMF	Probable Maximum Flood
'Ponds'	The 'direct rainfall' modelling process can result in water being caught between local ridges and depressions creating "ponds" these artefacts are normally the result of subtle changes in the ground data that has been sampled to create the DEM.
SAAR	Standard Annual Average Rainfall is the average annual rainfall across an area
SuDS	*Sustainable Drainage Systems*, which are designed to manage surface water flows in order to mimic the Greenfield run-off from an undeveloped site.
TUFLOW	TUFLOW is one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software. It simulates the complex hydrodynamics of floods and tides using the full 1D St Venant equations and the full 2D free-surface shallow water equations.
T_p	Time to Peak is the time delay between peak rainfall and peak river flow rate

1 Executive Summary

This flood modelling report has been undertaken to support the proposed redevelopment of the area known as Anglia Square, Norwich NR3 1DZ. The proposals are for a mixed-use scheme including retail and residential uses. According to Environment Agency surface water mapping the site is in an area at risk of surface water flooding. Consequently, to understand the risk to the site, and the potential changes in flood risk elsewhere as a result of the development proposals, a surface water flood model has been produced.

A two-dimensional direct rainfall hydraulic model of the Catton and Sewell catchment was constructed to understand the surface water flood risk to the site, and the potential impacts elsewhere as a result of the development. The results of this modelling study are to be used to support a planning application at the site and inform suitable flood mitigation measures for the proposed development.

The flood model has been based on the original Catton and Sewell model constructed in 2011 as part of the Norwich Surface Water Management Plan (SWMP). The original hydrological inputs to the model were updated, along with the LIDAR data. The model was run for the baseline scenario, with the existing Anglia Square topographic survey used to inform the site level. The model was then run for the proposed scenario with the proposed finished floor levels and mitigation measures included, to determine any vulnerable areas and offsite impacts. Direct rainfall hyetographs were applied as the boundary condition over the entire catchment, using the FEH13 DDF rainfalls and ReFH2 methodology. Due to the high URBEXT and BFIHOST values in the catchment, FEH guidelines recommend using the summer profile. Therefore, this was used for the model design, with sensitivity analysis on the winter profiles. The net rainfall was used to derive the hyetographs, as this accounts for several factors such as the area reduction factor and seasonal variation factor. The results of the net rainfall model are similar to the EA's risk of flooding from surface water mapping.
The model was simulated for a range of return periods for the present day and with consideration for the impacts of climate change.

The model was tested for sensitivity to several parameters including storm duration, inflows, Manning's roughness and infiltration parameters. Additional runs were also included as a rough validation exercise, based on the 27th May 2014 and 20th July 2014 historic events for which there is some evidence of flood extents. These sensitivity tests indicate that the model is relatively unaffected by changes in these parameters and validates well against known flood locations from the historic events.

Flood depth and extents maps were generated from the results.. The flood modelling has been undertaken to support the development proposals for Anglia Square and to determine mitigation measures, thus it may not be appropriate for other sites to make use of the results, especially at the edges of the modelled extent.

2 Introduction

2.1 Appointment

RHDHV were appointed by Weston Homes to build a direct rainfall hydraulic model to support a large mixed-use development at Anglia Square, Norwich NR3 1DZ. The existing site lies within a significant surface water flow path, therefore hydraulic modelling was required to determine the risk to the proposed development and any mitigation measures that may need to be included in the new scheme.

Norfolk County Council (NCC) were approached for initial comments in 2017, relating to an earlier application at the site by Weston Homes. NCC highlighted the surface water risk and identified the site to be within a Critical Drainage Area (CDA). NCC provided their Norwich Urban Surface Water Management Plan Model CDC2 (Catton Grove and Sewell catchment) to base the hydraulic model on. Given the age of the model, updates have been included for the latest analysis, such as the hydrological inflows and LIDAR data.

This report details the methodology used in developing the catchment model, including the hydrological analysis and hydraulic approaches, and presents the results and sensitivity analysis, as well as providing conclusions, limitations and recommendations.

2.2 Brief

In summary, the scope of the commission includes:

- An assessment of the catchment hydrology and the derivation of the critical storm events using the Flood Estimation Handbook.
- The construction of a two-dimensional (2D) hydraulic model of the Catton and Sewell catchment.
- Identification of the 'worst-case' flooding scenario between winter and summer seasons.
- Simulation of the baseline runs for five design storm events (1 in 30, 75, 100, 100 plus 20% climate change and 100 plus 40% climate change return periods).
- Simulation of the proposed development runs for five design storm events (1 in 30, 75, 100, 100 plus 20% climate change and 100 plus 40% climate change return periods).
- Sensitivity testing for the impact of:
    - Inflow Boundary (+20% and -20%);
    - Manning's Roughness (+20% and -20%);
    - Infiltration/Drainage Parameters (+20% and -20%);
    - Storm Duration (1 hour and 3 hour event);
    - Seasonal Change (Summer and Winter storm profiles).
- Rough calibration against two historic storm events in the catchment on 27th May 2014 and 20th July 2014.
- The production of flood maps of the different simulated model runs, scenarios and sensitivity tests.

2.3 Lead Local Flood Authority Pre-Application Comments

The Lead Local Flood Authority (LLFA) were consulted for advice and feedback on the modelling approach. The LLFA comments are included in **Appendix A**. These are summarised below:

- External inflows from adjacent catchments to be scaled up to 1 in 100 year plus 40% climate change rather than 20% climate change;
- 1 hour storm duration to be considered;
- Both summer and winter storm profiles to be considered to determine critical storm;
- Concerns over infiltration parameter using 7mm/hour to represent discharge to sewers and infiltration to ground. Requested including of Anglian Water sewer network within model;
- Ground truthing checks to be carried out;
- Flyover on the southern site boundary to be better represented in 2D domain, using variable levels;
- Culvert representing subway in original model to be removed since it was infilled in 2018;
- Threshold survey carried out along Magdalen Street to better understand risk to the properties;
- Model calibration based on the 2014 storm events;
- Further sensitivity testing to be carried out;
- Model stability checks to be carried out;
- Below ground car park in Block A to be set at or above ground level. Threshold level at car park entrance to be at least 300mm higher than 1 in 100 year plus climate change flood level;

Most of the points above have been addressed within this modelling report. However, some of the points were not considered to be feasible within the scope of this study. These are:

1) Including the Anglian Water sewer network within the model. This request is not reasonable given the scope of the study, which covers Anglia Square only and not the entire catchment. The original SWMP CDC2 model used a constant rate of 7mm/hour to represent drainage to the public sewer and this was accepted by NCC. Details of Anglian Water sewers covering the whole catchment were not available at the time of building the model. However, losses have been accounted for within the net rainfall hyetographs in the updated model. Recent discussions with the LLFA highlighted the requirement to assess the impact of discharging to sewers which could be flowing at capacity during an extreme event. This will be investigated further and the conclusions will be presented following submission.
2) Locating the below ground car park at or above ground level. This cannot be achieved due to spatial constraints. In addition, it is not practicable to raise the threshold of the entrance to the car park 300mm above the 1 in 100 year (+40%CC) flood level, as it would be very difficult for cars to access the car park. Instead, a flood warning system and inclusion of a self-raising flood barrier at the car park entrance have been discussed within the Flood Risk Assessment.

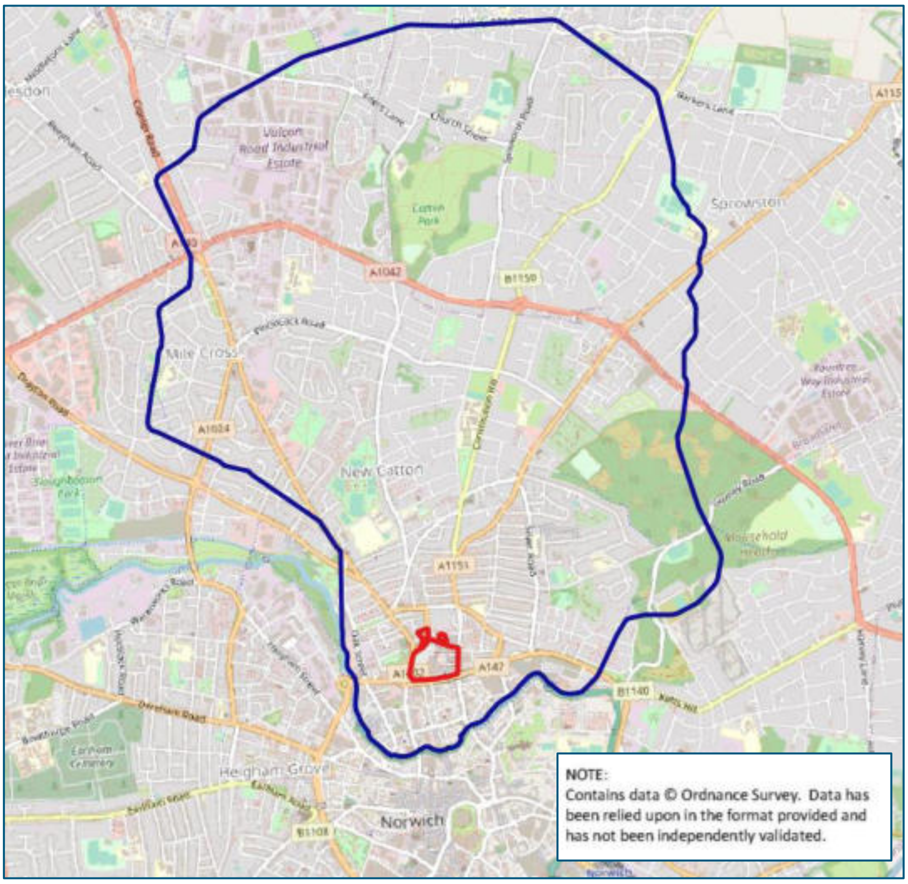
It was acknowledged during a meeting with the LLFA flood risk team in March 2022 that some further work would be required following the submission, relating to the inclusion of Anglian Water sewers, flows into the catchment from adjacent catchments and consideration of offsite impacts. This work will be carried out and summarised in a further technical note.

3 The Study Area

3.1 Catchment Location

The Catton and Sewell catchment extent (hereafter referred to as 'the Catchment') is shown in Figure 3-1 in blue, with Anglia Square ('the Site') in red. The Catchment covers an area of approximately 8.5 km^2 (850 ha). The Catchment is located immediately north of the River Wensum and Norwich city centre. The Catchment boundary shown in Figure 3-1 matches that used in the original CDC2 model, and therefore was considered suitable for this analysis. In addition, by modelling the catchment, it would better demonstrate the main overland flow paths which come from the north of the site rather than just applying rainfall to the site itself.

Figure 3-1: Catton and Sewell catchment boundary (from original SWMP model)



The catchment is predominantly urban, consisting of residential areas and roads, although the open space areas of Catton Park and Mousehold Heath are included.

The FEH web-service (https://fehweb.ceh.ac.uk/) provides standardised catchment descriptors for the UK, which enables the national data set to be used to predict the catchment run-off characteristics for most of the UK. As part of this web-service a catchment area for any point of interest can be obtained.

3.1.1 Watercourses

The hydrological setting of the Catchment is summarised below and is also discussed in the FRA.

a) Meanders of the River Wensum are approximately 200m south and west of the site. The confluence of the River Wensum and River Yare are downstream of Norwich city centre.

b) A lost watercourse known as the Dalymond Dyke is understood to pass close to the site. It is understood that this lost watercourse originally followed the natural streams and formed an integral part of the historic sewer system on Norwich. The Dalymond Dyke now forms part of the Anglian Water sewer network so it not considered an open watercourse.

3.2 Site Inspections

No site inspections were conducted by the hydraulic modelling team as part of this study. However, a topographic survey of Anglia Square and photographs have been analysed.

4 Methodology

4.1 Choice of Approach

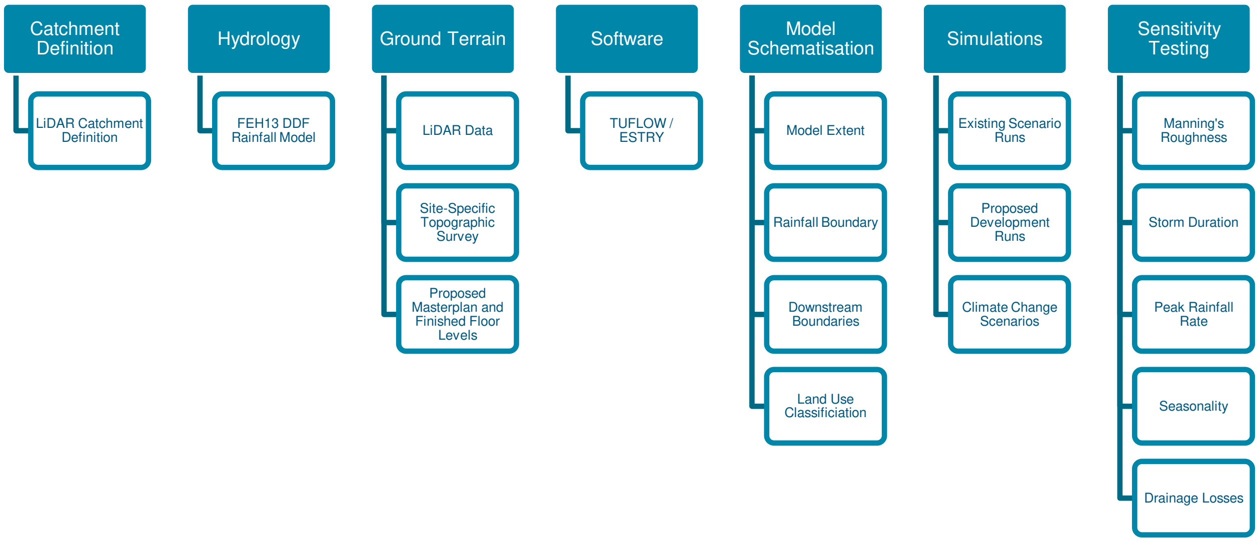
As there were no open watercourses in the catchment and the primary flood source is overland flow from surface water, a Direct Rainfall approach was considered most suitable. The Direct Rainfall method applies rainfall directly to a two-dimensional model of the catchment as design rainfall events and the hydraulic model simulates the subsequent overland flow of rainfall.

It should be noted that all hydrological and hydraulic methodologies have limitations and sources of uncertainty, and, therefore, the most appropriate method should be considered based on the type of catchment and the sources of flood risk.

A limitation of Direct Rainfall includes uncertainty regarding infiltration and run-off rates to sewers. As the capacity of the Anglian Water sewer network across the catchment is unknown and outside of the scope of the study, a similar approach to infiltration to sewers was initially used as in the existing CDC2 model, which allowed a constant rate of 7mm/hour as an infiltration boundary to represent losses to sewers or infiltration to the ground. However, a subsequent discussion with the LLFA suggested that 7mm/hour is not considered representative of the whole catchment. Instead, the net rainfall hyetographs were applied which accounted for losses across the catchment based on the catchment characteristics, and the infiltration boundary was removed.

Figure 4-1 provides an overview of the modelling methodology based on the Direct Rainfall approach. The numerical flood model has been developed using a systematic approach of analysing the LiDAR and topographical survey of the site, determining suitable hydrological conditions and then combining the hydraulic characteristics.

Figure 4-1: Methodology Overview



4.2 Hydrological Approach

The Direct Rainfall method required the derivation of suitable rainfall hyetographs applied to the hydraulic model in the form of rainfall timeseries data. The FEH Web Service (https://fehweb.ceh.ac.uk/) provided catchment descriptors, which were used alongside the ReFH2 software to generate rainfall depth duration frequency (DDF) estimates. ReFH2 was used to assess the critical storm duration, and the hyetographs were prepared from the DDF estimated as the rainfall boundary.

4.3 Hydraulic Modelling Approach

Based on the study area and the considerations above, it was considered most suitable to implement a 2D[1] flood modelling regime, using the TUFLOW computational engine. As no watercourses or culverts are located within the catchment, there is no 1D element so the ESTRY 1D component is not required.

The TUFLOW/ESTRY computational engine has been benchmarked by the Environment Agency (Environment Agency, 2013), and is considered suitable for predicting flood levels and depths, flow velocities, and flood hazard ratings associated with tidal and fluvial flood inundation as well as direct rainfall modelling.

Based on experience of development of 1D/2D numerical flood models for assessment of site-specific flood risks, the TUFLOW/ESTRY solver is considered appropriate for the simulation of the baseline scenario, and for testing of potential future mitigation options.

[1] *A 2D solver enables an estimation of water level and flow rates in a dual vector direction, usually forwards and backwards along a channel, and perpendicular to the channel. These solvers are usually slower than 1D solvers, and can encounter problems when dealing with small channel widths (less than 3 model cell widths).*

5 Data Sources

Several sources of information have been used in this study. Table 5-1 provides a list of the data used in the development of the hydrological assessment and hydraulic model. The data quality has been assessed in accordance with the Multi-Coloured Manual (Flood Hazard Research Centre & Envrionment Agency, 2013) and scored accordingly where:

- 1 - Best possible;
- 2 - Data with known deficiencies;
- 3 - Gross assumptions; and
- 4 - Heroic assumptions.

Table 5-1: Data type and sources

Data Type	Sub Type	Source	Date	Score	Comment
Hydrology	Historic Flooding Records	Norfolk County Council	2014	3	Description of flooded areas from the Norwich Urban Area Investigation Report (2014). LLFA requested the model to be calibrated using this information.
2D Geometry	Site-Specific Topographic Survey	Weston Homes	2016, updated 2022	1	Best available data covering the site
	LiDAR Data	Environment Agency	2020	1	The best data available for the study area was the 2019 composite dataset.
	NextMap 5m Data	Environment Agency	2021	2	Where gaps in the Environment Agency LiDAR dataset were present, this has been substituted with NextMap 5m DTM data.
Surface Roughness	Aerial Photography	Various	2021	2	Aerial photography provided a means to confirm the surface roughness assigned by the Ordnance Survey data.
	Original Model Materials Layers	Various	2011	2	Original materials layers were used where possible as these covered the catchment area and were previously accepted by NCC. Materials layers were checked in the vicinity of the site and updated where necessary based on aerial imagery and topographic survey data.

5.1 Ground Truthing

The LLFA requested that ground truthing checks were carried out to ensure the EA LiDAR data was representative of the ground levels. Some inspection points were selected across the site area where site-specific topographic survey data was available, and the topographic survey levels were compared to the LiDAR levels. As no survey data was available offsite, this was the best method of ground truthing, with the assumption that any differences between the survey data and LiDAR within the site boundary would be similar across the catchment. Figure 5-1 shows the locations of the inspection points and Table 5-2 contains the elevations and differences.

Figure 5-1: Ground Truthing Coverage

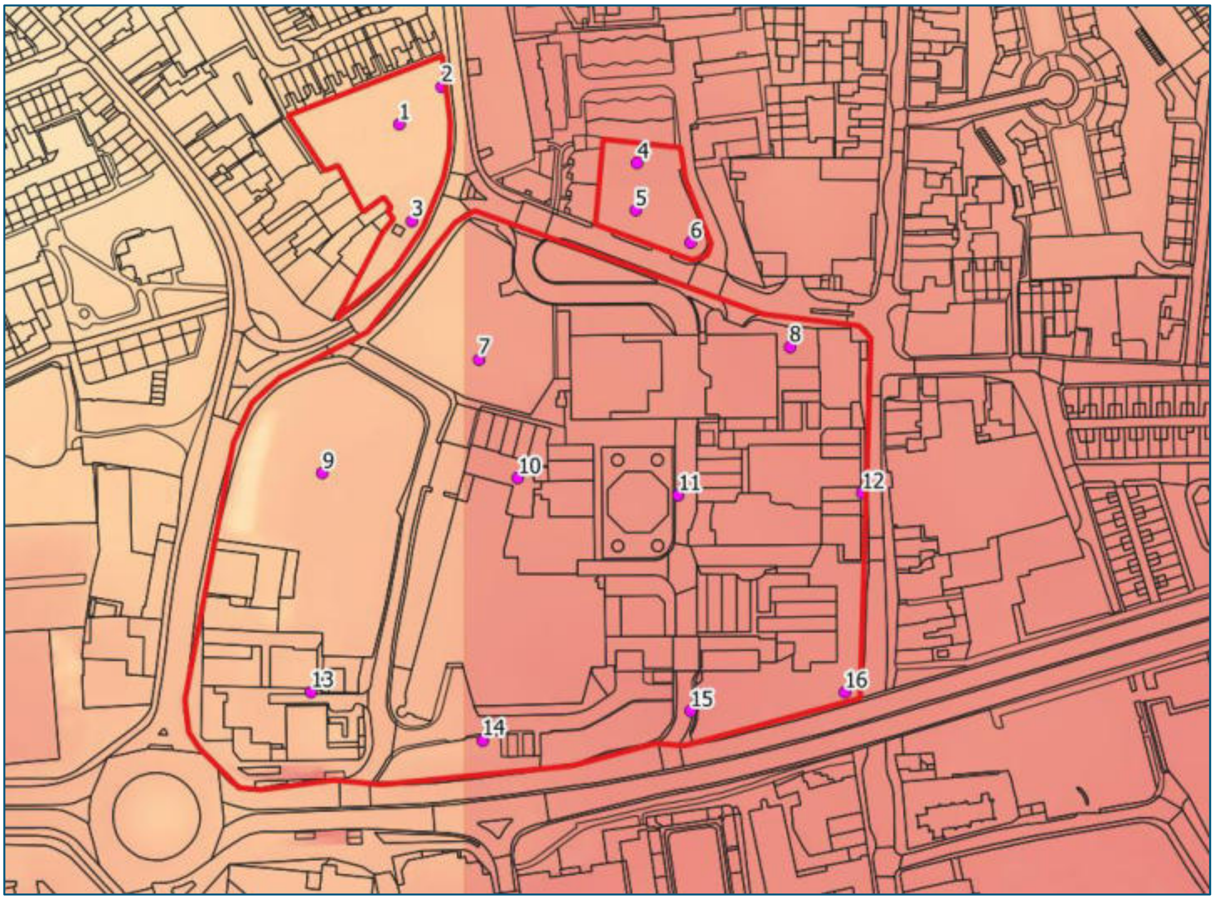


Table 5-2: Ground Truthing Results

Inspection Point	Z LIDAR (m AOD)	Z TOPO (m AOD)	Difference (m)
1	5.41	5.37	0.04
2	5.45	5.39	0.06
3	5.16	5.09	0.07
4	4.00	3.97	0.03
5	4.16	4.09	0.07
6	4.28	4.20	0.08
7	5.19	5.12	0.07
8	3.35	3.30	0.05
9	4.71	4.70	0.01
10	3.93	3.84	0.09
11	3.92	3.90	0.02
12	3.51	3.55	0.04

Inspection Point	Z LIDAR (m AOD)	Z TOPO (m AOD)	Difference (m)
13	4.82	4.79	0.03
14	4.48	4.38	0.10
15	2.77	2.77	0.00
16	3.53	3.47	0.06

The EA website (data.gov.uk) states that all LiDAR data has a vertical accuracy of +/-15cm (0.15m). All of the points interrogated above show the LIDAR data is within +/-0.15m of the topographic survey, and therefore can be considered to be acceptable for the purpose of this modelling study.

6 Hydrological Analysis Summary

6.1 FEH13 DDF Rainfall Model

The FEH13 DDF Rainfall Model was used to estimate rainfall depths for a given return period and storm duration. The catchment boundary identified on the FEH Web Service contained inconsistencies, notably stopping short of covering the site regardless of where the catchment outflow point was selected. Therefore, catchment descriptors from the closest catchment boundary to the site were used. FEH catchment descriptors are included in **Appendix A** along with the hyetographs.

Rainfall depths were retrieved for a range of return periods and storm durations for both the Summer and Winter storm profiles. These are summarised below in ***Table 6-1***.

Table 6-1 DDF Rainfall depths [mm]

Season	Storm Duration [hr]	Return Period		
		30-year	75-year	100-year
Winter	1	16.8	20.8	22.2
Summer	1	30.6	37.9	40.4
Winter	3	27.1	34.0	36.6
Summer	3	43.5	54.7	58.7

Given the high URBEXT and BFIHOST values generated for the catchment, FEH guidelines recommend using the summer profile. As the summer 3-hour storm duration resulted in the greatest rainfall depths, this was considered to be the critical storm duration and was used for the design runs. The ReFH2 software was used to generate hyetographs based on the DDF peak rainfall data above. The LLFA requested that both winter and summer profiles were considered, along with the 1-hour storm duration. Therefore, these runs were also simulated as part of the sensitivity tests.

The gross rainfall was initially used to create the hyetographs, as this did not include any losses. The losses to sewers or to the ground were then included as part of the TUFLOW model as a second rainfall polygon with a negative value of 7mm/hour. However, following discussions with the LLFA, it was determined that 'Net Rainfall'[2] data would be most appropriate for use with the surface water model. This is due to this data accounting for several factors such as the area reduction factor and seasonal variation factor, as well as taking into account catchment infiltration parameters. Notably, the 'Net Rainfall' hyetographs did not include any losses to sewers, which represents a worst-case scenario assuming sewers are at capacity. Therefore, the 'Net Rainfall' data was utilised for input into the hydraulic model as it provided the most representative design rainfall for the catchment. The second rainfall polygon which applied the infiltration loss was removed from the model for the final set of model simulations.

[2] *Net Rainfall applies the FEH equations to determine the resultant rainfall that would run-off taking into account the catchment descriptors for the area. The Design Rainfall does not factor for the interception or evaporation of rainfall, and therefore if the Design Rainfall was used, these factors would need to be defined within the rainfall run-off model.*

6.2 Climate Change Allowances

The latest climate change allowances for rainfall were applied to the rainfall hyetographs input into this model. **Table 6-2** reproduces the Environment Agency climate change allowances for peak rainfall intensity for England.

Table 6-2: Peak Rainfall Intensities, Environment Agency 2020.

Allowance Category	Total Potential Anticipated Change for the '2020s' (2015 to 2039)	Total Potential Anticipated Change for the '2050s' (2040 to 2069)	Total Potential Anticipated Change for the '2080s' (2070 to 2115)
Upper End	10%	20%	40%
Central	5%	10%	20%

Accordingly, the climate change allowances for the 2080s have been applied to the hyetographs to provide a direct rainfall assessment. Therefore, an increase of 20% and 40% was applied to the direct rainfall hyetographs for the 1 in 100 year event.

6.3 External Flows

The TUFLOW model included boundary conditions around the edge of the catchment which enabled flows from adjacent catchments to flow into the model domain (2d_bc_ST_NOR2_02.shp). The inflows for these boundaries were taken from surface water models covering the adjacent catchments and so it is unclear how they have been generated. For this reason, the 1 in 100 year (+20%CC) external inflow boundary was used during the 1 in 100 year (+40%CC) simulation. The LLFA pre-application comments requested the model to be extended to cover the adjacent catchments and simulated for the 1 in 100 year (+40%CC) rainfall event. However, this was beyond the scope of the study, therefore the external flows were simply scaled up, using the 1 in 100 year and 1 in 100 year (+20%CC) event, to create external inflows for the 1 in 100 year (+40%CC) event.

7 Hydraulic Modelling

7.1 Model Schematisation

The hydraulic model schematisation was based on an inspection of the hydrological characteristics and geometric features within the study. The schematisation of the 2D model domain is discussed below to provide clarity of approach.

The original SWMP model included a pedestrian subway beneath St Crispins Road to the southwest of Anglia Square. This was represented in the model as a section of 1D culvert within ESTRY, enabling surface water to flow beneath the road at this location. Following receipt of the pre-application comments from the LLFA, it is understood that this subway was infilled in 2018, and so the section of 1D culvert was removed from the model. As this was the only 1D element in the model, an .ecf file was not required for the final model runs.

7.2 2D Domain

The basis of the 2D domain was developed using Environment Agency LiDAR DTM data. A 2m cell size was used which would allow the main flow paths to be picked up without compromising the simulation time.

7.2.1 Digital Elevation Model

The 2019 composite 0.50m grid resolution LiDAR data set was retrieved from the Environment Agency open source web portal and covers the model extent.

7.2.2 Z-Shape Geometry

The site-specific topographic survey, updated in 2022, was then used to include more accurate ground levels within Anglia Square. It was noted that the upper and lower levels of Anglia Square was not accurately picked up in the LiDAR, therefore a number of Z-shape polygons were included to better represent the finished floor levels (FFL) across the existing site.

The existing St Crispins Road flyover, which forms the southern boundary, was also not represented very well within the original CDC2 model. This was included in the existing and proposed models as a Z-shape which used topographic levels to represent the slope from 4.48m AOD to 8.63m AOD.

The original model set the FFL of all buildings across the catchment to consistently be raised 0.10m above the LiDAR elevation, and all roads to be set -0.125m below the LiDAR elevation. The purpose of this was to represent the building thresholds in areas which could not be surveyed. The LLFA acknowledged this approach but requested that building thresholds along Magdalen Street are surveyed as some of the premises to the immediately east and south east of Anglia Square are known to have thresholds at the same level as the pavement. The buildings and thresholds cannot be surveyed due to access constraints. Instead, the model was updated to remove the buildings along Magdalen Street from the Z-shape layer, essentially lowering them all in the assumption that all threshold levels of these properties were at ground level, matching the LiDAR. This is a conservative approach but presents a worst-case scenario.

The proposed development model runs included all ground FFLs of the buildings where known, as Z-shapes. The basement car park located in Block A is within the surface water flow path and therefore identified as a vulnerable part of the development. The LLFA requested that the basement car park was set at ground floor level, or the entrance to the car park is raised 300mm above the 1 in 100 year (+40%CC)

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flood level. Neither of these options are feasible, therefore a flood barrier (self-raising or manual) is intended to be located at the entrance to the car park which will be triggered at the onset of flooding. To understand the flood depths that could occur at the entrance of the basement car park, the 'flood barrier' was included as a wall using a '2d_za' layer, with an elevation of 10m, to prevent the wall from being overtopped. It should be noted that this will not necessarily be the design level of the barrier. This prevents water from entering the car park and also made it possible to measure the flood depths at this point in the modelled events.

As it is not possible to prevent surface water flows from passing through the site without causing an offsite risk to others, a system had to be designed whereby flows would continue to pass through the site in a managed approach. Therefore, it is recommended that the roads and pedestrian footways throughout the site are lowered in the centre to enable water to flow through the site. Walkways and roads were lowered based on an approximate crossfall of 1:80, using Z-points and Z-shapes to create TINS throughout the site to direct flow to the southeastern corner in a similar manner to the existing overland flow path.

7.2.3 Surface Roughness

Definition of surface roughness within the floodplain is important especially for areas of shallow flow, where the surface roughness factor of the ground can have an impact on the flow velocity, due to the impacts of friction. Surface roughness values were determined using industry standard methods (Chow, 1959).

A global Manning's *n* roughness of 0.035 was applied to the whole catchment initially. The materials file was then read in to specify roughness values for individual features.

The materials layers for the original CDC2 model were used for the most part and applied as a .tmf file within TUFLOW. This was reviewed in the vicinity of the site to ensure the land types were as accurate as possible in the local area. Where necessary, the materials layers were updated. The original Manning's roughness values were used, although the buildings roughness value was increased from 0.04 to 0.1 as it was considered to be more representative of flows passing through buildings. Table 7-1 provides the surface roughness values (as Manning's *n* values) used for each land use classification.

Table 7-1: Definition of Surface Roughness Values (Chow, 1959)

Material Code	Manning's Roughness 'n'	Description
999	0.035	Default Roughness
109	0.020	General Surface: Manmade
110	0.030	General Surface: Natural
111	0.040	General Surface: Residential Yards
112	0.100	Buildings
113	0.020	Roads Tarmac
114	0.080	Trees
115	0.025	Tracks/Dirt Roads
116	0.020	Pavement
117	0.035	Land Unclassified

7.3 Boundary Conditions

The boundary conditions represent the inflow and outflow conditions of the model and at any external model connections. The purpose of the boundary conditions is to provide a realistic simulation of the way in which water flows in and out of the modelled domain. For this model the following conditions have been used:

a. Rainfall boundary;

b. Infiltration boundary;

c. External flow boundaries; and

d. Outflow boundary.

Rainfall was applied to the whole catchment of the model as rainfall hyetographs as described in Section 4. A 2d_rf boundary covering the entire catchment has been included within the model to apply this boundary.

The original CDC2 model and report assessed the influence of the Anglian Water sewer system within the catchment and determined that a constant 7mm/hour loss to the sewers was a reasonable estimate. Therefore the same approach was initially adopted here. The losses to the sewer network were represented as a second '2d_rf' boundary with a negative inflow applied at regular intervals. However, following discussion with the LLFA, it was decided that the 'Net Rainfall' would be more representative of the catchment and the second '2d_rf' polygon was removed from the model.

As previously noted, the original model contained external inflows from adjacent catchments. The original inflows have been applied for all previously modelled return periods, as it was not possible to extend the updated CDC2 model to cover adjacent catchments within this study. As requested by the LLFA, the 1 in 100 year (+40%CC) external inflow was scaled up for the critical design run.

An outflow boundary was applied around the edge of the model using the '2d_bc' layer from the original model. This applied a HQ normal depth boundary around the catchment boundary, to enable water to leave the model based upon a stage-discharge relationship relating to the ground surface slope.

8 Model Simulations

8.1 Overview and Naming Convention

Given the various model input parameters such as seasonality, storm duration etc. a coded naming convention was applied to the model run files, summarised in Table 8-1. The final runs were labelled '_012'. The following key should be used to understand the nomenclature:

- *Existing* – Existing/Baseline
- *Proposed* – Proposed Development included
- *P* – Pluvial Return Period
- *CC* – % Climate Change Allowance
- *hr* – Storm Duration in Hours (sensitivity test)
- *SM* – Summer Storm Profile
- *WT* – Winter Storm Profile

Table 8-1 Model Run Files

Name [.tcf] and Results File	Scenario	Return Period [year]	Storm Duration [hr]	Epoch	Version
Design Runs					
Anglia_Square_Existing_P0030_3hr_SM_013	Existing	30	3	2020	1
Anglia_Square_Existing_P0075_3hr_SM_013	Existing	75	3	2020	1
Anglia_Square_Existing_P0100_3hr_SM_013	Existing	100	3	2020	1
Anglia_Square_Proposed_P0030_3hr_SM_013	Proposed	30	3	2020	1
Anglia_Square_Proposed_P0075_3hr_SM_013	Proposed	75	3	2020	1
Anglia_Square_Proposed_P0100_3hr_SM_013	Proposed	100	3	2020	1
Climate Change Runs					
Anglia_Square_Existing_P0100_20CC_3hr_SM_013	Existing	100	3	2080	1
Anglia_Square_Existing_P0100_40CC_3hr_SM_013	Existing	100	3	2080	1
Anglia_Square_Proposed_P0100_20CC_3hr_SM_013	Proposed	100	3	2080	1
Anglia_Square_Proposed_P0100_40CC_3hr_SM_013	Proposed	100	3	2080	1
Sensitivities					
Anglia_Square_Duration_P0100_1hr_SM_013	1 Hour Duration Sensitivity Summer	100	1	2020	1
Anglia_Square_Duration_P0100_1hr_WT_013	1 Hour Duration Sensitivity Winter	100	1	2020	1
Anglia_Square_Season_P0100_3hr_WT_013	3 Hour Winter Sensitivity	100	3	2020	1
Anglia_Square_n+20_P0100_3hr_SM_013	Manning's Roughness + 20%	100	3	2020	1
Anglia_Square_n-20_P0100_3hr_SM_013	Manning's Roughness - 20%	100	3	2020	1

Anglia_Square_P+20_P0100_3hr_SM_013	Pluvial Inflow +20%	100	3	2020	1
Anglia_Square_P-20_P0100_3hr_SM_013	Pluvial Inflow - 20%	100	3	2020	1
Validation					
Anglia_Square_Historic_P27MAY2014_013	39.4mm Rainfall applied over 4hr 15mins	N/A	4.25	N/A	1
Anglia_Square_Historic_P20JULY2014_013	45.8mm Rainfall applied in 1 hour	N/A	1	N/A	1

8.2 Return Periods

The model was simulated for three design events, these were:

- 1 in 30 year design storm;
- 1 in 75 year design storm;
- 1 in 100 year design storm.

8.3 Significant Issues

In the development of this numerical flood model, no significant issues have been determined. The model runs within normal operating parameters, and the outputs have been visually verified through anecdotal evidence.

8.4 Choice of Seasonality

The hydrological assessment identified that the summer storm resulted in the greatest rainfall depths, therefore this was chosen as the design scenario. The model was run for a duration of 6 hours, to allow surface water flows to pass through the catchment and the site following the end of the storm.

8.5 Validation & Calibration

Calibration is the adjustment of a model's parameters, such as roughness, and hydraulic structure coefficients, so that it reproduces observed data to an acceptable accuracy.

No calibration data was available for the model and therefore calibration has not been undertaken.

The LLFA highlighted two significant rainfall events within the catchment, which were detailed in the report published by NCC titled 'Investigation Report into the flooding within the Norwich Urban Area during the summer of 2014' (Ref: FIR008). Section 5 details the historic events as:

- 27th May 2014 - 39.4mm was recorded as falling in 4 hours 15 minutes by the Heigham rainfall monitoring station. This intensity of rainfall equates to a 1 in 16 year rainfall event.

- 20th July 2014 – Hourly rainfall totals from the Norwich Airport rainfall monitoring station show 45.8mm fell in 1 hour from 14:00. This intensity of rainfall equates to a 1 in 121 year rainfall event.

Hyetographs were designed to replicate these events, with 39.4mm rainfall split across a 4.25 hour time period for the May 2014 event and 45.8mm rainfall split over 1 hour for the July 2014 event. A minimal infiltration factor was applied to represent drainage losses.

Although flood depths and levels are not recorded in the document, notable locations flooded within the Dalimond Catchment are:

- North Walsham Road (one property flooded in May 2014 event)
- Oak Lane (three properties flooded in May 2014, 2 properties flooded in July 2014)
- Orchard Close (three properties flooded in May 2014, two flooded in July 2014)
- Edge of Mousehold Heath (external flooding)

A full validation cannot be undertaken without knowing the exact locations of the properties or depth of flooding, but a crude validation through visual analysis was carried out.

- North Walsham Road – The May 2014 model run shows flooding to properties in a similar location to that indicated on Map 3 of the Norwich Urban Area Investigation report.
- Oak Lane – Both the May 2014 and July 2014 model runs resulted in significant flooding at the junction of Oak Lane and Mile Cross Lane, an area highlighted in the report as having several recorded flood events.
- Orchard Close – The model extent doesn't cover this area, therefore no results are available.
- Edge of Mousehold Heath – Near the junction of Mousehold Road and Gurney Road, flooding is noted in both 2014 events.

Although the validation demonstrates that the model results are broadly similar to the flooding experienced in the 2014 events, the validation exercise is limited in its precision. A second validation exercise was carried out, comparing the model results in the 1 in 30 and 1 in 100 year events to the EA's risk of surface water flooding maps for 'medium' and 'high' frequency events. The comparison shows good correlation between the two sets of results, which suggests the use of the 'Net Rainfall' hyetographs and the losses included within the ReFH2 model represent the catchment and the area around the site well. Figure 8-1 and Figure 8-2 show the comparison maps, and the full maps are included in **Appendix B**.

Figure 8-1: Comparison between 1:100 model results and EA's RoFSW map

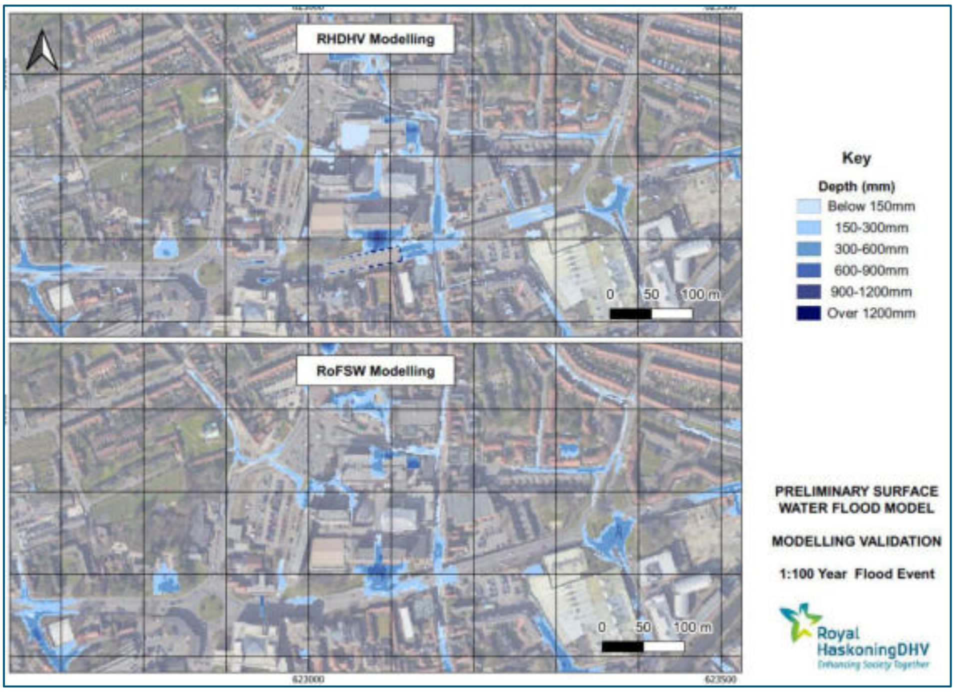
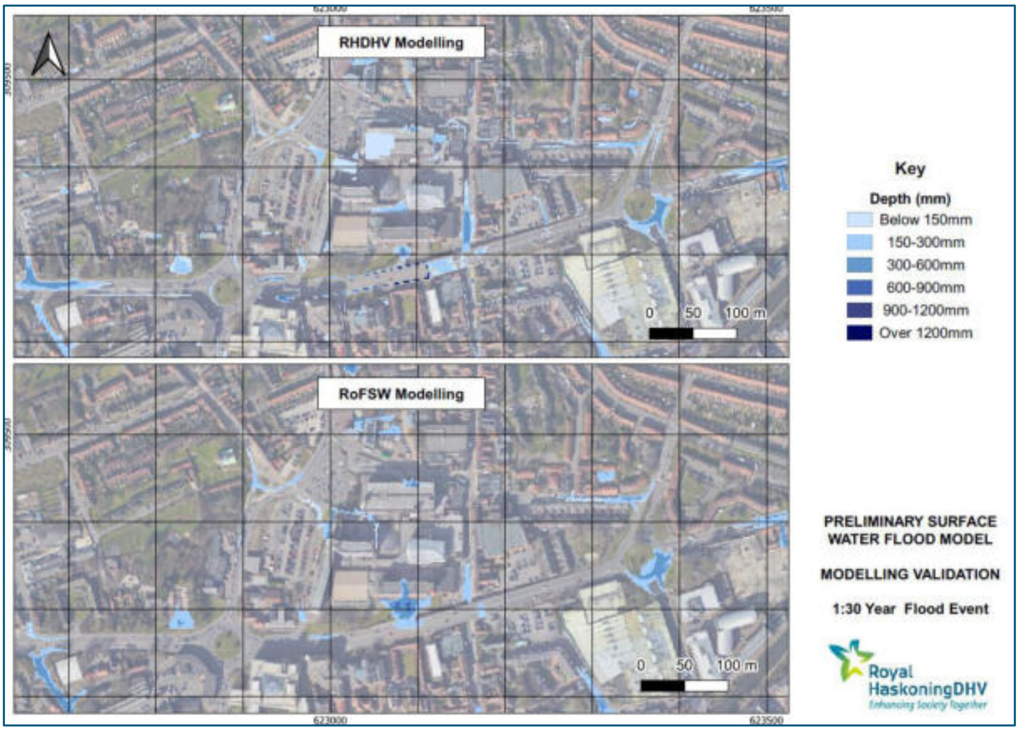


Figure 8-2: Comparison between 1:30 model results and EA's RoFSW map



8.6 Sensitivity Analysis

A range of sensitivity tests were performed to understand the impact on water levels due to variations in antecedent conditions as a substitute for a more-precise validation exercise.

Sensitivity analysis was performed to understand the models tolerance to physical parameters. The 1 in 100-year design event for the baseline scenario was used to assess model sensitivity.

Sensitivity runs were carried out by varying the following parameters by +/-20%:

- Rainfall Hyetograph /Inflow - The direct rainfall boundary and external inflow boundaries have been varied by +/-20%;
- Manning's Roughness – All materials values, including the default roughness value, have been varied by +/-20%;

In addition, the 3 hour winter profile was run as well as the 1 hour summer and winter storm profiles, to determine the variability of the season and storm duration.

To determine how sensitive the model is to changes in the input variables, a sensitivity rating has been determined, in respect of the absolute change in flood level, and the relative change in flood level. The ratings are set out in Table 8-2.

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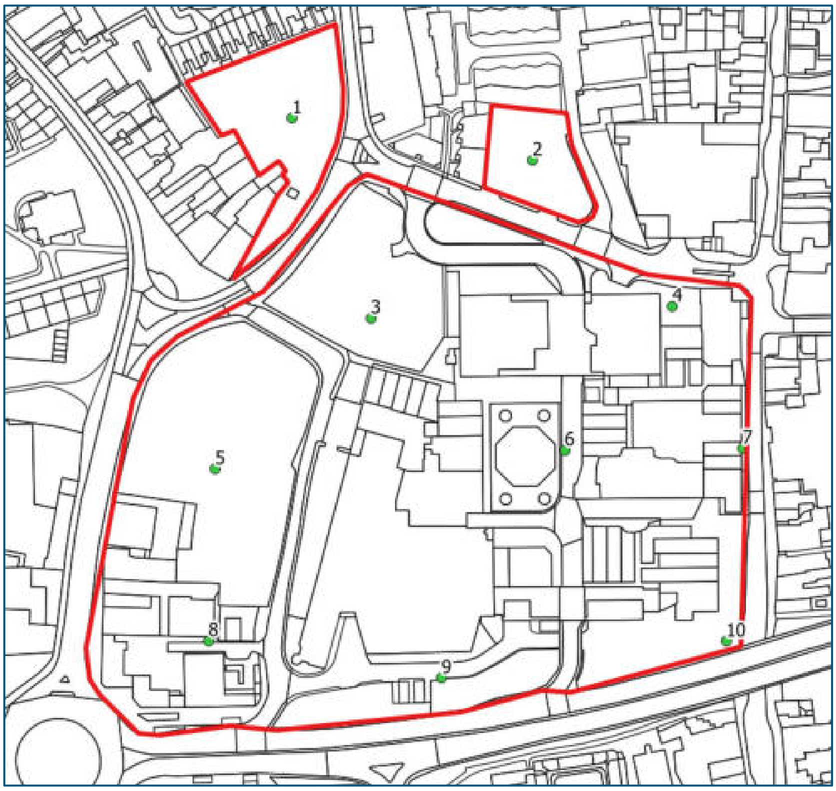
Table 8-2: Sensitivity Ratings

	Proportional Change in Flood Depth			
Absolute Change in Flood Depth	0 to 2%	2 to 5%	5 to 10%	Greater than 10%
0 to 25mm	Nominal	Negligible	Moderate	Severe
25 to 50mm	Negligible	Negligible	Moderate	Severe
50 to 150mm	Moderate	Moderate	Severe	Severe
Greater than 150mm	Severe	Severe	Severe	Severe

8.6.1 Review of Sensitivity

A number of inspection points were digitised across the Anglia Square site. Depth grid results were then interrogated at each inspection point for the 1 in 100 year event, and each of the sensitivity runs. The inspection points are shown in Figure 8-3.

Figure 8-3: Sensitivity Review Inspection Points



The sensitivity matrix table in**Table *8-3*: Sensitivity Matrix Table** Table 8-3 summarises the flood depths of the baseline 1 in 100 year event and each of the sensitivity runs. The average depth change has been calculated relative to the baseline along with the relative percentage change from the baseline. A sensitivity rating has then been applied to each, based upon Table 8-2.

Table 8-3: Sensitivity Matrix Table

Scenario	Inspection Point Maximum Flood Depth (m)										Average Depth Change from Baseline		Sensitivity Rating
Absolute Change in Flood Depth	1	2	3	4	5	6	7	8	9	10	Absolute (m)	Relative (%)	
Baseline	0.020	0.002	0.001	0.532	0.033	0.187	0.044	0.045	0.86	0.002	0.1726		
Rainfall Boundary (+20%)	0.023	0.140	0.001	0.600	0.035	0.256	0.040	0.045	0.904	0.002	0.032	18.54	Severe
Rainfall Boundary (-20%)	0.019	0.002	0.001	0.187	0.030	0.132	0.003	0.045	0.274	0.002	0.103	59.67	Severe
Manning's Roughnes s (+20%)	0.020	0.002	0.001	0.534	0.034	0.189	0.043	0.045	0.86	0.002	0.0004	0.23	Nominal
Manning's Roughnes s (-20%)	0.020	0.002	0.001	0.526	0.031	0.185	0.035	0.045	0.86	0.002	0.0019	1.10	Nominal
Variation in Season and Storm Duration													
Winter Profile 3hr	0.018	0.002	0.001	0.118	0.027	0.044	0.003	0.045	0.226	0.002	0.1240	71.84	Severe
Summer Profile 1hr	0.020	0.002	0.001	0.132	0.032	0.059	0.004	0.045	0.226	0.002	0.1203	69.69	Severe
Winter Profile 1hr	0.016	0.002	0.001	0.031	0.025	0.014	0.003	0.045	0.118	0.002	0.1469	85.11	Severe

The results for the sensitivity runs show that although flood depths differ slightly across the site, the difference is within 100mm, for all sensitivity runs. The Manning's roughness values are likely to be "noise" differences, assumed to be as a result of the interpolation and convergence between model time-steps and do not lead to any increase in flood extent or peak flood level.

As expected, the model results vary the most significantly due to changes to the changes in rainfall hyetographs and seasonal profile, with the winter profile resulting in the most reduction in flood depth. In addition, the use of the 1 hour storm duration for the summer profile also results in a relatively large change from the baseline.

The sensitivity matrix demonstrates that the model:

- Is sensitive to changes in the rainfall hyetograph;
- Is not sensitive to changes to the Manning's roughness values;
- Is very sensitive to seasonal profile;
- Is very sensitive to storm duration.

Given the above, the model is considered to provide a robust prediction of the storm events simulated.

9 Model Results

Model results are presented in the form of mapped flood extent and depth outputs in **Appendix B**.

Flood depths of less than 0.05m (50mm) were removed from the depth maps to provide a clearer presentation of areas at risk of flooding.

9.1 Summary of Results

9.1.1 Present Day

The flood extents broadly match the SWMP mapping and EA surface water maps. The overland flow path from the north of the catchment is clearly visible, even in the 1 in 30 year return period event. EA surface water mapping indicates a vulnerable area within the site boundary to be to the south of the existing buildings, where water appears to pool against the flyover. Additionally, the south east part of the site and Magdalen Street are flooded in the extreme scenarios. The model results show this to be the case for the baseline existing and proposed scenarios, although the flood extent within the site appears to be greater than the EA mapping suggests.

9.1.2 Impacts of Climate Change

Climate change is predicted to increase flood extents in those areas highlighted as being at most risk in the present day scenario. The model results can therefore be used to investigate suitable mitigation measures and inform flood warning systems within the site.

9.1.3 Model Health

The model simulation log files (TUFLOW *.tlf* files) show that the model is healthy, with peak and final mass errors of less than 1% for all of the simulated events. There were no recorded model warnings during any of the simulations for all events. The .tlf files are summarised for the 1 in 30, 1 in 100 and 1 in 100 (+40%CC) events in **Appendix C**.

10 Assumptions, Limitations and Recommendations

10.1 Assumptions

Hydrological and hydraulic models are constructed from empirical and numerical components that, by definition, have assumptions built into their underlying parameters and calculations. Other assumptions also arise in their development due to uncertainty in, or absence of suitable input data (e.g. percentage run-off or losses to sewers). Therefore, it is important to understand what assumptions have been made in the development of a model so as to appreciate the limitations of the results and draw appropriate conclusions.

The key assumptions made during this study are listed below:

10.1.1 Hydrological Assumptions

The hydrological analysis assumes:

- FEH13 design storm profiles for a 3 hour design storm duration across the whole catchment;
- Net rainfall was used as this included catchment specific losses;
- Average Standard Annual Average Rainfall (SAAR) and Design Rainfall depths across the whole Catchment;

10.1.2 Hydraulic Assumptions

The 2D hydraulic model assumes:

- The application of a single rainfall boundary to apply inflow hyetographs covering the whole catchment;
- The Digital Elevation Model has derived from filtered Environment Agency LiDAR data is accurate and representative of the topography of the catchment;
- 2D surface roughness values based on the original CDC2 model are acceptable. Verification of roughness in the vicinity of the site has been undertaken, using online aerial photography and reviewed against Chow (1959);

10.2 Limitations

The limitations in any numerical model are generally related to the quality and comprehension of the available input data. In particular to this study, the detail and availability of the antecedent conditions limits the accuracy to which the simulated design events reflect the response of the catchment.

Calibration data in the form of recorded depths and accurate locations of flooding historic events was not available, therefore the model could only be crudely validated against the 2014 storm events.

There were several data limitations to the construction of the model. These included unknown threshold levels of individual properties offsite and limited information on external inflows from adjacent catchments into the study area. The assumptions used in the original CDC2 modelling carried out by NCC were accepted and applied to this study in the absence of data on the threshold levels and Anglian Water sewer network.

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10.3 Recommendations

The model was initially built using the gross rainfall hyetographs with drainage applied as losses at a rate of 7mm/hour, which represented a worst-case scenario given the rate of 7mm/hour is very low.

Further to discussions with the LLFA, they identified that they believed that this rate was not representative of the whole catchment. Consequently, it was decided that the net rainfall hyetographs should be used, as these included losses in the form of seasonal variation factor and area reduction factors. The negative rainfall boundary was therefore removed, as the losses where factored into the input hyetograph.

The net rainfall model results present a more likely representation of the flood risk to the catchment, which is demonstrated by the similarities with the EA's online surface water mapping. It is therefore recommended that these results should be used to design mitigation measures, as this demonstrates a worst-case scenario and would result in more robust flood mitigation in the event that sewers are at capacity.

Discussions with the LLFA also highlighted that further work will be required to better represent the Anglian Water sewer network in the vicinity of the site and the external flows coming from adjacent catchments. This work will be carried out following submission and provided to the LLFA in due course.

11 Conclusions

A two-dimensional direct rainfall hydraulic model of the Catton and Sewell catchment was constructed to understand the surface water flood risk to Anglia Square, Norwich NR3 1DZ. The purpose of the modelling study is to support a planning application at the site and to inform suitable flood mitigation measures for the proposed development.

The model has been based on the original Catton and Sewell model constructed in 2011 as part of the Norwich Surface Water Management Plan (SWMP). It was necessary to build a model to cover the whole catchment, given the main flood risk results from an overland surface water flow path originating in the north of the catchment, which flows through the site. Discussions with the LLFA highlighted the age of the original model and the need to update certain elements, therefore a hydrological analysis was carried out and the hyetographs were updated using the FEH13 Depth Duration Frequency rainfall depths. The latest EA LiDAR data was used to cover the catchment outside of the site boundary, while the topographic survey of the site and proposed development plans were used to create the geometry of Anglia Square.

During the hydrological analysis, a comparison was made between the summer and winter profiles. FEH guidelines recommend using the summer profile due to high URBEXT and BFIHOST values. The summer profile and 3 hour storm duration were the critical storm event, so this was used in all design events. Sensitivity tests were carried out on the winter profile and 1 hour storm duration. It was noted that the 1 hour storm duration resulted in much shallower flood depths than the design storm duration.

The original model applied a constant infiltration value of 7mm/hour to represent drainage losses. This approach was initially used for the model, as specific information on the Anglian Water sewer network was unknown and it was outside the scope of the project to include the sewer network. The gross rainfall was used to derive the hyetographs, with the drainage losses applied in TUFLOW as a negative rainfall boundary. Subsequent discussion with the LLFA highlighted that this may not be representative of the whole catchment. Therefore, the ‘Net Rainfall’ hyetographs were used as these included losses, although notably did not include any losses to sewers, thus representing a worst-case scenario.

Materials layers from the original model were used for most of the catchment. The local area close to the site was checked and materials layers amended where necessary.

The model was simulated for a range of return periods for the present day and with consideration for the impacts of climate change.

The model was tested for sensitivity to several parameters including storm duration, rainfall and Manning’s roughness. Additional runs were also included as a rough validation exercise, based on the 27th May 2014 and 20th July 2014 historic events for which there is some evidence of flooding locations. These sensitivity tests indicate that the model is relatively unaffected by changes in these parameters and validates well against known flood locations from the historic events. Flood extents and depths were also compared against the EA Risk of Surface Water flood maps, and showed the model results to reflect this well.

Flood depth and extents maps were generated from the results. It is not recommended that the results be used at the individual property scale given the coarse resolution relative to the size of properties. It is however considered suitable to inform the Flood Risk Assessment for the proposed development at Anglia Square and to determine mitigation measures.

12 Bibliography

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Appendix A: FEH Data

VERSION	"FEH CD-R	Version	4.0.0	exported a	16:11:19	GMT	Tue	01-Feb-22
CATCHMEI	GB		622800	309650	TG 22800 09650			
CENTROID	GB		623425	311523	TG 23425 11523			
AREA	10.6375							
ALTBAR	29							
ASPBAR	215							
ASPVAR	0.18							
BFIHOST	0.859							
BFIHOST19	0.861							
DPLBAR	3.4							
DPSBAR	17.9							
FARL	1							
FPEXT	0.1456							
FPDBAR	0.556							
FPLOC	0.964							
LDP	5.93							
PROPWET	0.27							
RMED-1H	11.2							
RMED-1D	27.4							
RMED-2D	34.7							
SAAR	615							
SAAR4170	634							
SPRHOST	16.43							
URBCONC1	0.885							
URBEXT19	0.3853							
URBLOC19	0.923							
URBCONC2	0.928							
URBEXT20	0.3899							
URBLOC20	0.953							
C	-0.02352							
D1	0.27622							
D2	0.36542							
D3	0.25417							
E	0.31058							
F	2.48834							
C(1 km)	-0.024							
D1(1 km)	0.275							
D2(1 km)	0.37							
D3(1 km)	0.255							
E(1 km)	0.31							
F(1 km)	2.498							

P0030_3hr_SM

Time	Rain
0	0
0.01	0.040443
0.066667	0.044408
0.133333	0.049218
0.2	0.054312
0.266667	0.059883
0.333333	0.066131
0.4	0.073156
0.466667	0.081082
0.533333	0.090055
0.6	0.100255
0.666667	0.111905
0.733333	0.125281
0.8	0.140736
0.866667	0.158729
0.933333	0.179867
1	0.204988
1.066667	0.235283
1.133333	0.27255
1.2	0.319713
1.266667	0.382095
1.333333	0.471474
1.4	0.627752
1.466667	0.997533
1.533333	0.645658
1.6	0.494359
1.666667	0.406742
1.733333	0.344623
1.8	0.296926
1.866667	0.258686
1.933333	0.227185
2	0.200748
2.066667	0.178256
2.133333	0.158921
2.2	0.142164
2.266667	0.127543
2.333333	0.114715
2.4	0.103407
2.466667	0.0934
2.533333	0.084513
2.6	0.076596
2.666667	0.069523
2.733333	0.06319
2.8	0.057506
2.866667	0.052395
2.933333	0.047791
3	0

P0075_3hr_SM

Time	Rain
0	0
0.01	0.05084
0.066667	0.055949
0.133333	0.062043
0.2	0.068325
0.266667	0.075356
0.333333	0.083244
0.4	0.09212
0.466667	0.102141
0.533333	0.113494
0.6	0.126409
0.666667	0.141173
0.733333	0.15814
0.8	0.177765
0.866667	0.200638
0.933333	0.227543
1	0.25956
1.066667	0.298229
1.133333	0.345874
1.2	0.406272
1.266667	0.486307
1.333333	0.601182
1.4	0.802324
1.466667	1.279171
1.533333	0.830614
1.6	0.63734
1.666667	0.525246
1.733333	0.445628
1.8	0.384386
1.866667	0.335205
1.933333	0.294631
2	0.260533
2.066667	0.23149
2.133333	0.206496
2.2	0.184814
2.266667	0.165879
2.333333	0.149254
2.4	0.13459
2.466667	0.121603
2.533333	0.110064
2.6	0.099778
2.666667	0.090586
2.733333	0.082352
2.8	0.074959
2.866667	0.068309
2.933333	0.062315
3	0

P0100_3hr_SM

Time	Rain
0	0
0.01	0.054588
0.066667	0.060152
0.133333	0.066628
0.2	0.073382
0.266667	0.080942
0.333333	0.089425
0.4	0.098973
0.466667	0.109754
0.533333	0.121972
0.6	0.135876
0.666667	0.151774
0.733333	0.170051
0.8	0.191199
0.866667	0.215856
0.933333	0.244874
1	0.279421
1.066667	0.321167
1.133333	0.372633
1.2	0.437915
1.266667	0.524474
1.333333	0.648794
1.4	0.866578
1.466667	1.383226
1.533333	0.899192
1.6	0.690476
1.666667	0.569364
1.733333	0.483284
1.8	0.41703
1.866667	0.363793
1.933333	0.319851
2	0.282905
2.066667	0.251422
2.133333	0.22432
2.2	0.2008
2.266667	0.180255
2.333333	0.162211
2.4	0.146292
2.466667	0.132191
2.533333	0.119658
2.6	0.108486
2.666667	0.098499
2.733333	0.089552
2.8	0.081518
2.866667	0.07429
2.933333	0.067776
3	0

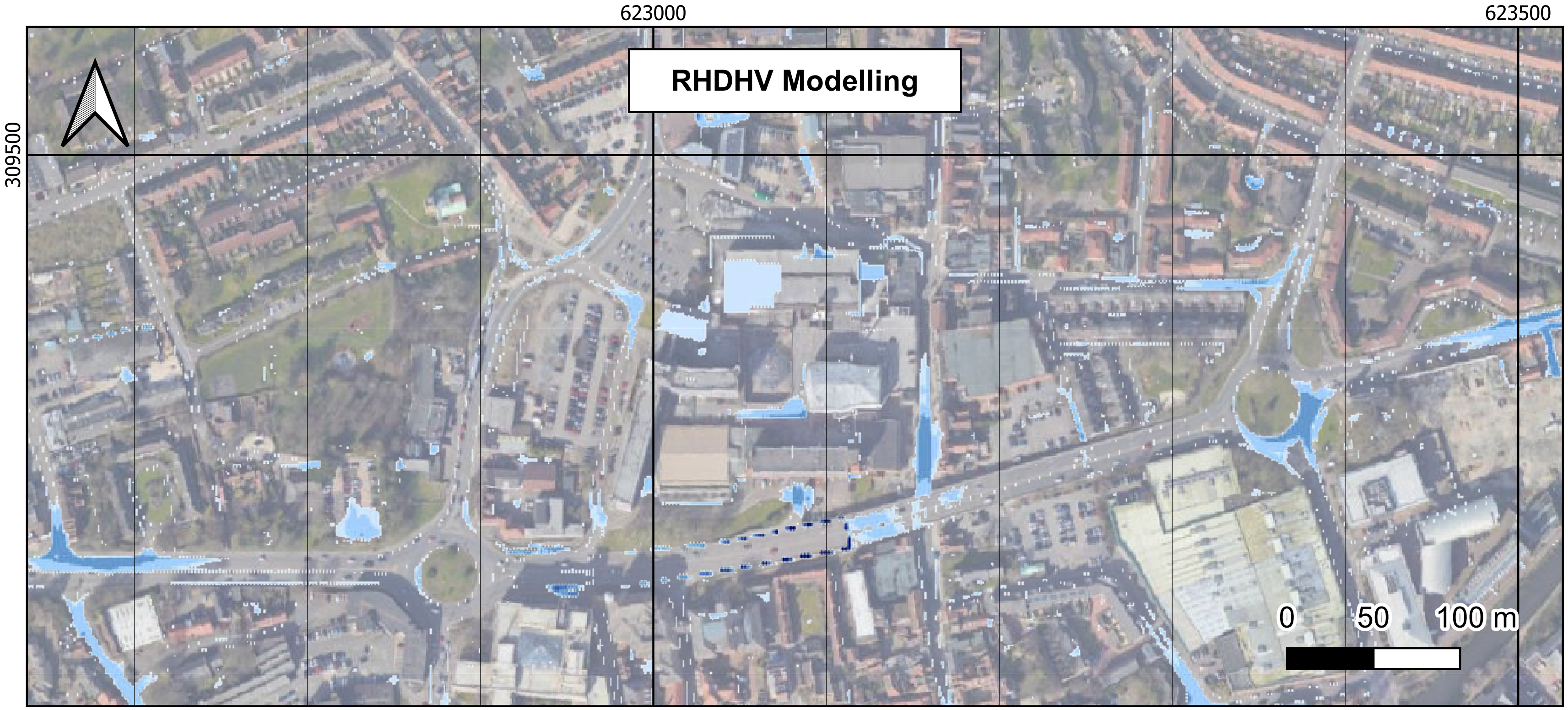
P0100_20CC_3hr_SM

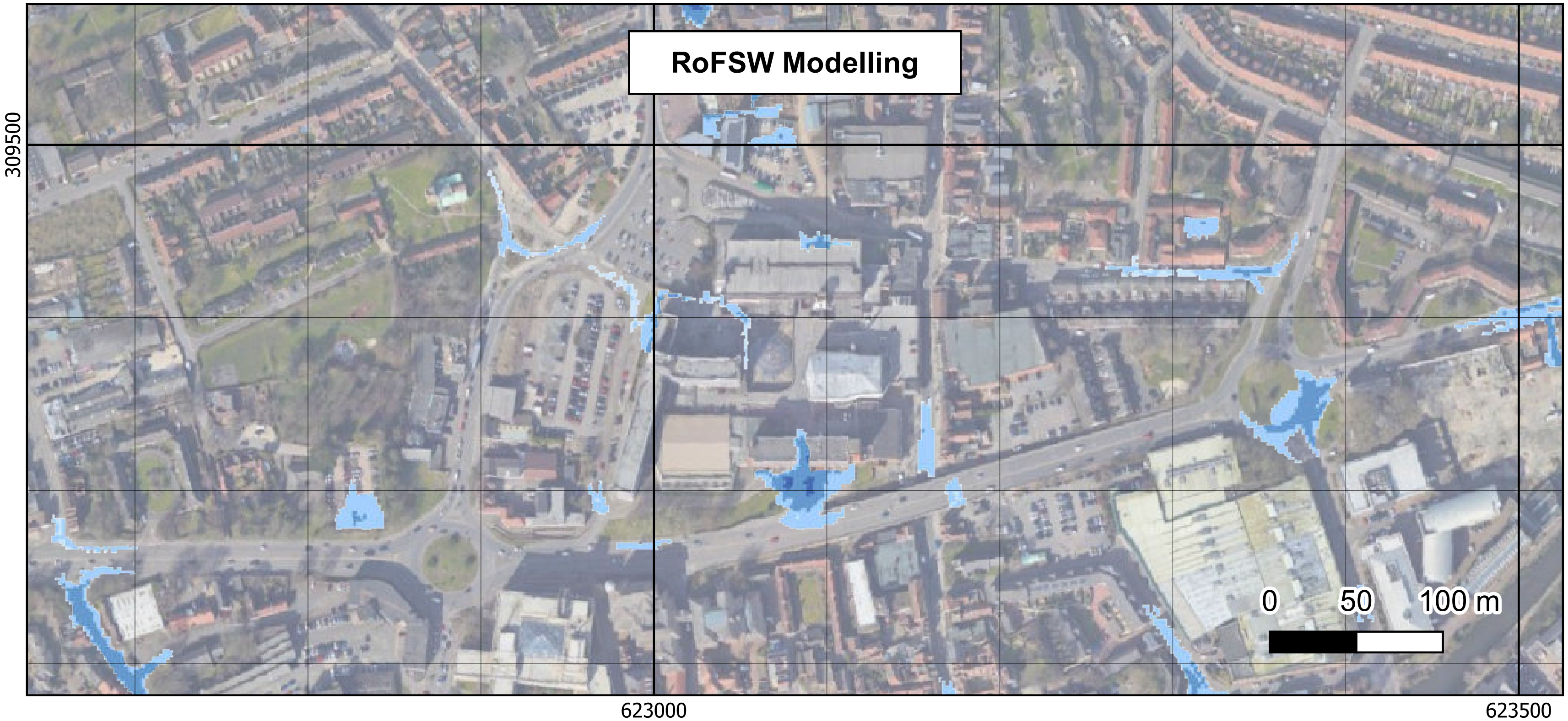
Time	Rain
0	0
0.01	0.065505
0.066667	0.072182
0.133333	0.079953
0.2	0.088059
0.266667	0.09713
0.333333	0.10731
0.4	0.118768
0.466667	0.131705
0.533333	0.146367
0.6	0.163051
0.666667	0.182129
0.733333	0.204061
0.8	0.229439
0.866667	0.259028
0.933333	0.293849
1	0.335305
1.066667	0.385401
1.133333	0.44716
1.2	0.525498
1.266667	0.629369
1.333333	0.778552
1.4	1.039894
1.466667	1.659871
1.533333	1.07903
1.6	0.828571
1.666667	0.683237
1.733333	0.579941
1.8	0.500436
1.866667	0.436552
1.933333	0.383821
2	0.339486
2.066667	0.301707
2.133333	0.269184
2.2	0.24096
2.266667	0.216306
2.333333	0.194654
2.4	0.17555
2.466667	0.158629
2.533333	0.14359
2.6	0.130183
2.666667	0.118199
2.733333	0.107462
2.8	0.097822
2.866667	0.089148
2.933333	0.081331
3	0

P0100_40CC_3hr_SM

Time	Rain
0	0
0.01	0.076423
0.066667	0.084212
0.133333	0.093279
0.2	0.102735
0.266667	0.113318
0.333333	0.125195
0.4	0.138562
0.466667	0.153656
0.533333	0.170761
0.6	0.190227
0.666667	0.212483
0.733333	0.238071
0.8	0.267679
0.866667	0.302199
0.933333	0.342824
1	0.391189
1.066667	0.449634
1.133333	0.521686
1.2	0.613081
1.266667	0.734264
1.333333	0.908311
1.4	1.21321
1.466667	1.936516
1.533333	1.258868
1.6	0.966666
1.666667	0.79711
1.733333	0.676598
1.8	0.583841
1.866667	0.509311
1.933333	0.447791
2	0.396067
2.066667	0.351991
2.133333	0.314048
2.2	0.28112
2.266667	0.252357
2.333333	0.227096
2.4	0.204808
2.466667	0.185067
2.533333	0.167521
2.6	0.15188
2.666667	0.137899
2.733333	0.125373
2.8	0.114125
2.866667	0.104006
2.933333	0.094886
3	0

Appendix B: Flood Maps





Key

Depth (mm)

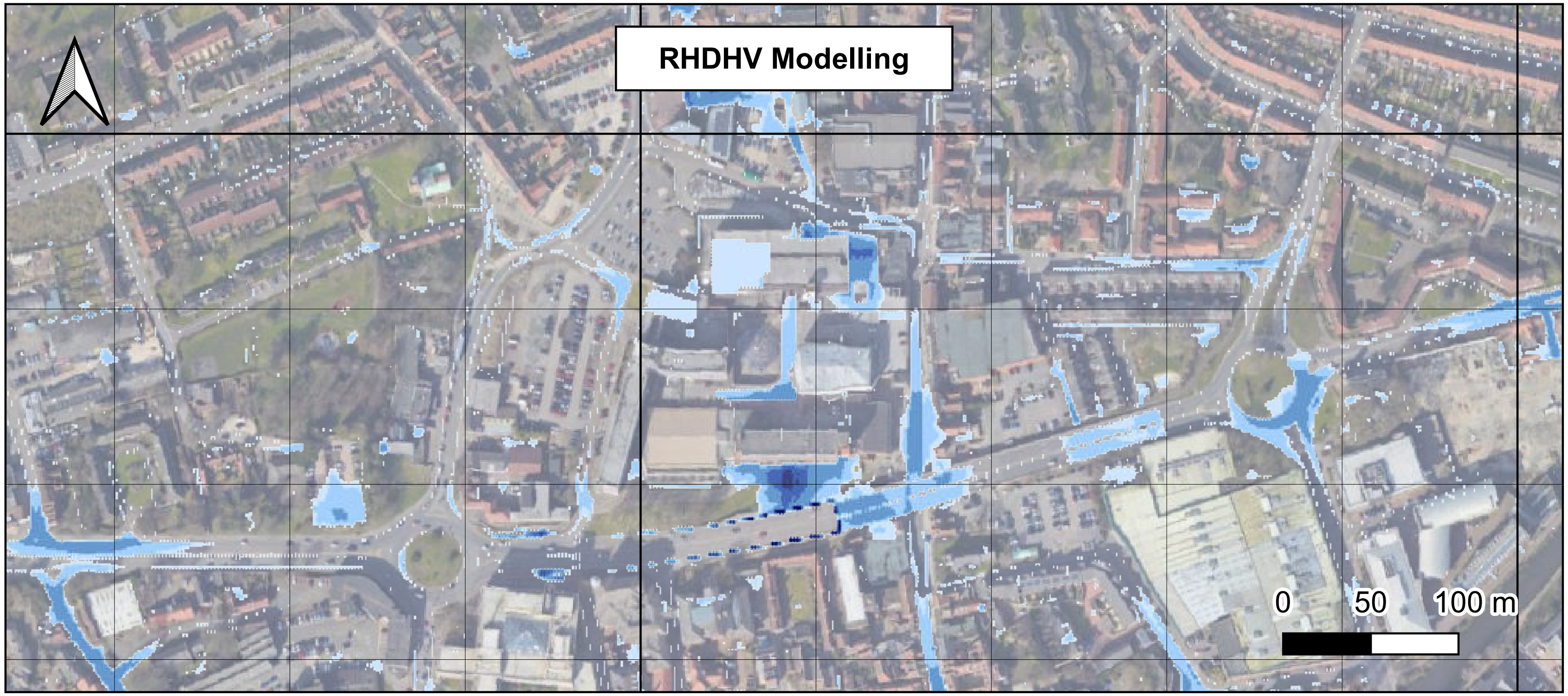
- Below 150mm
- 150-300mm
- 300-600mm
- 600-900mm
- 900-1200mm
- Over 1200mm

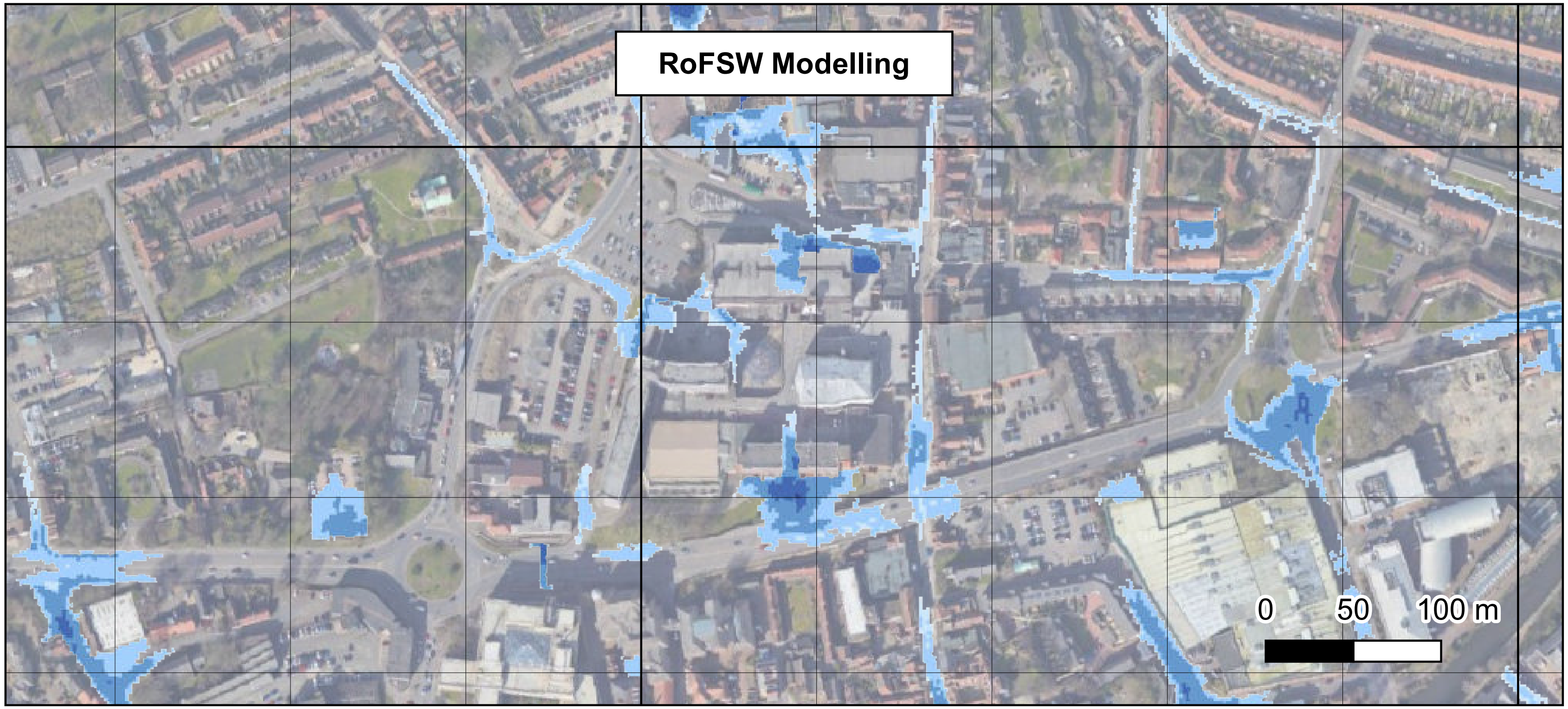
PRELIMINARY SURFACE WATER FLOOD MODEL

MODELLING VALIDATION

1:30 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together





Key

Depth (mm)

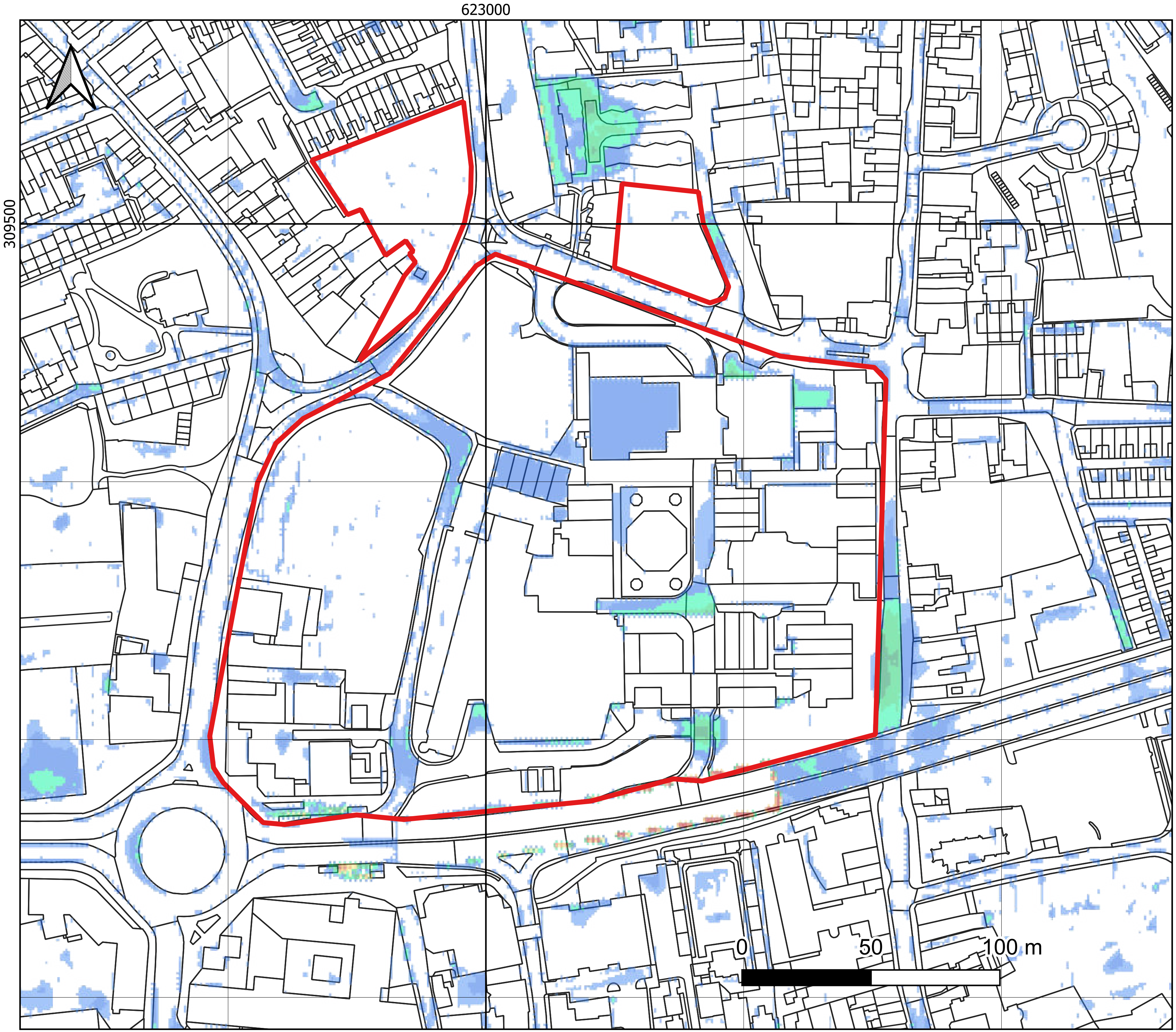
- Below 150mm
- 150-300mm
- 300-600mm
- 600-900mm
- 900-1200mm
- Over 1200mm

PRELIMINARY SURFACE WATER FLOOD MODEL

MODELLING VALIDATION

1:100 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Depth (m)

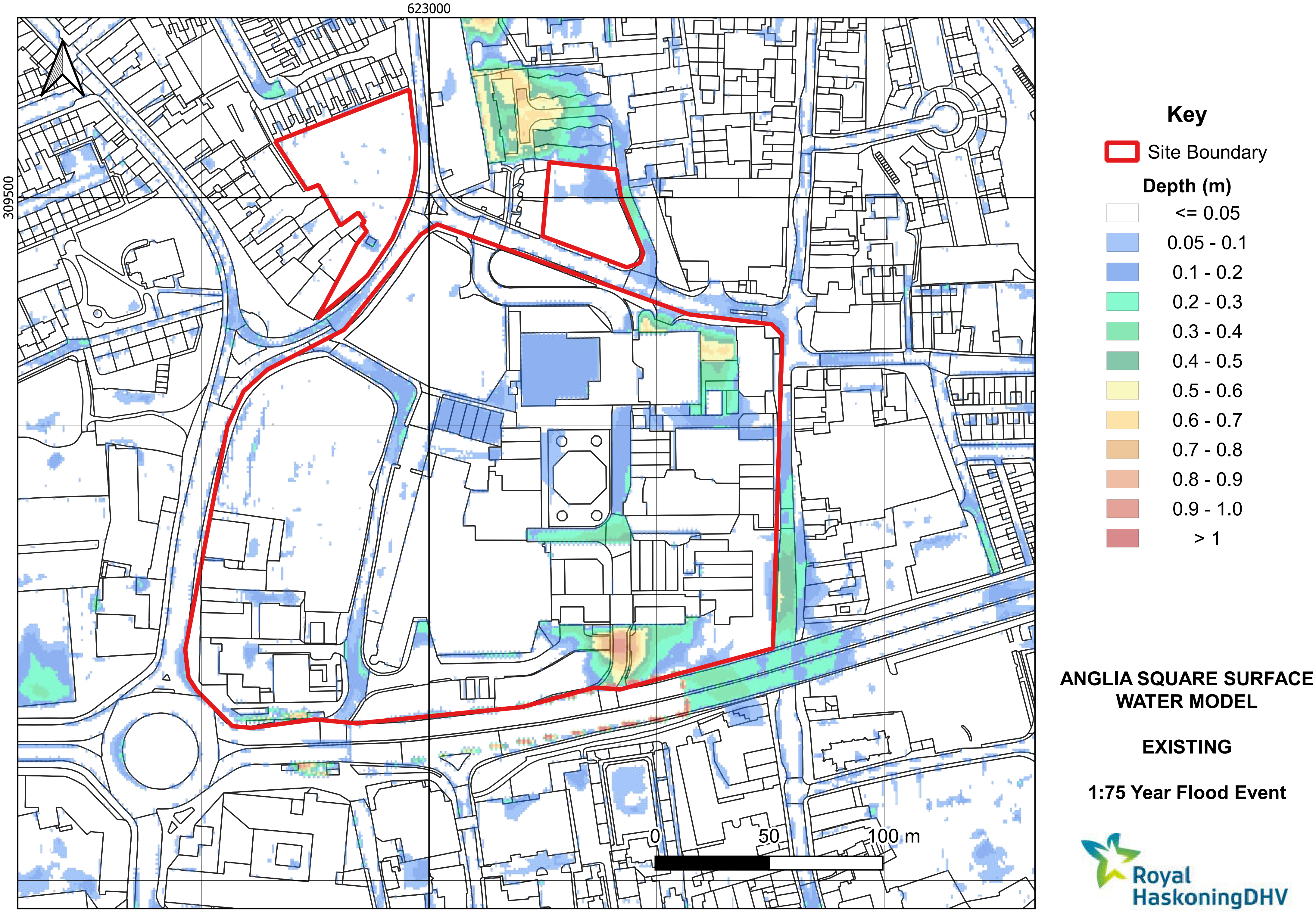
<= 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
> 1

ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:30 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together

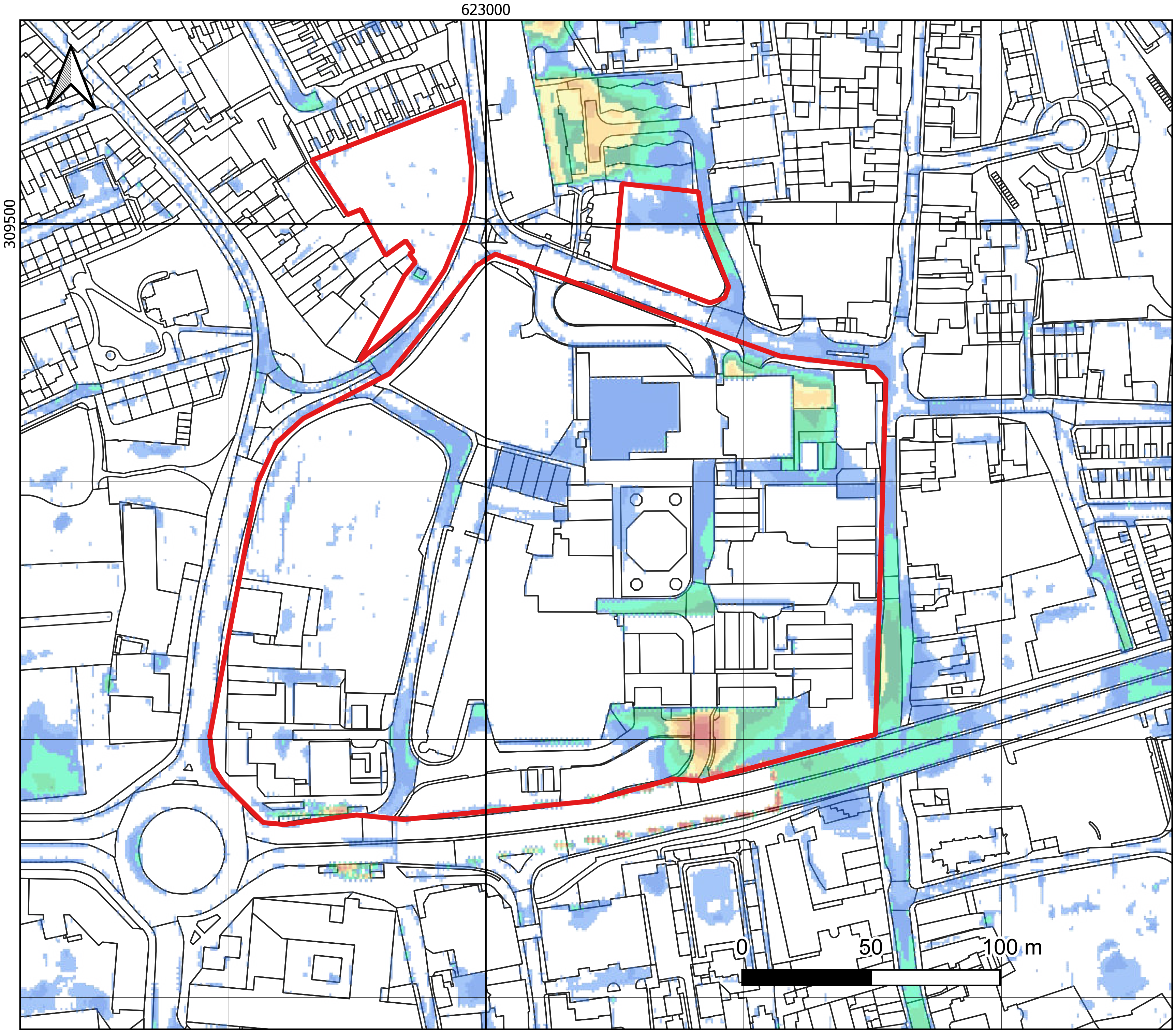


ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:75 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Depth (m)

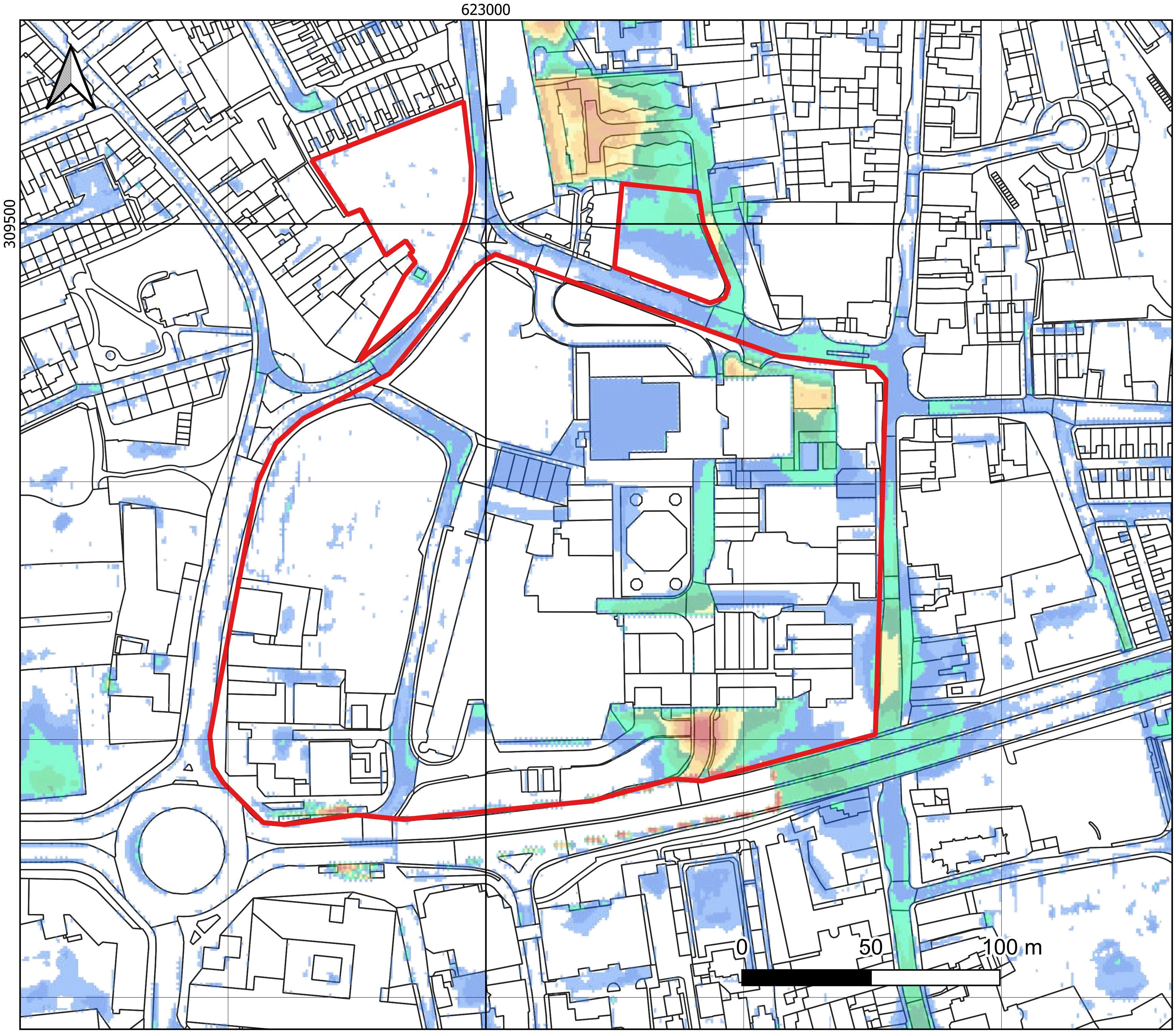
- <= 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1.0
- > 1

ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:100 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Depth (m)

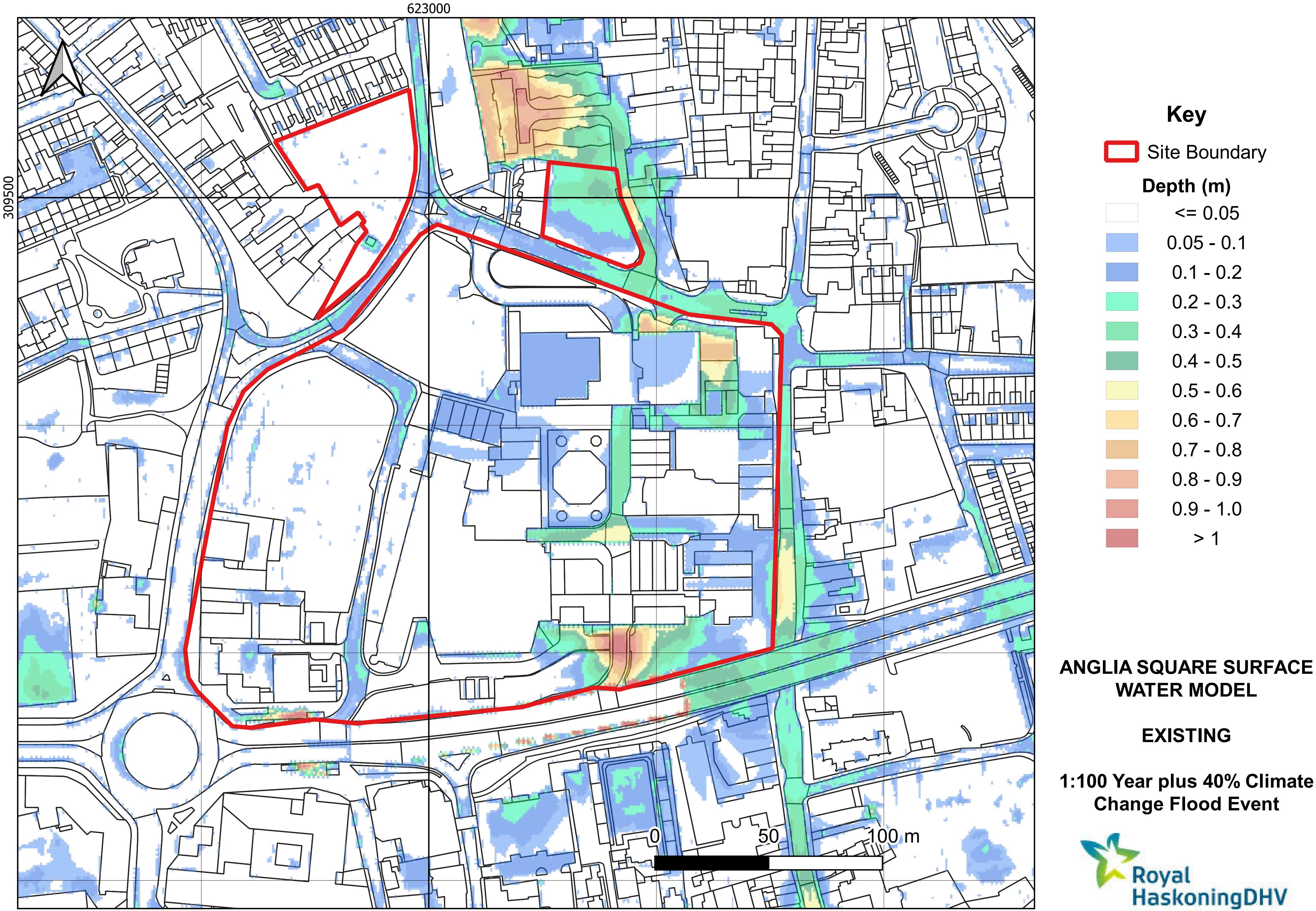
	<= 0.05
	0.05 - 0.1
	0.1 - 0.2
	0.2 - 0.3
	0.3 - 0.4
	0.4 - 0.5
	0.5 - 0.6
	0.6 - 0.7
	0.7 - 0.8
	0.8 - 0.9
	0.9 - 1.0
	> 1

ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:100 Year plus 20% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together

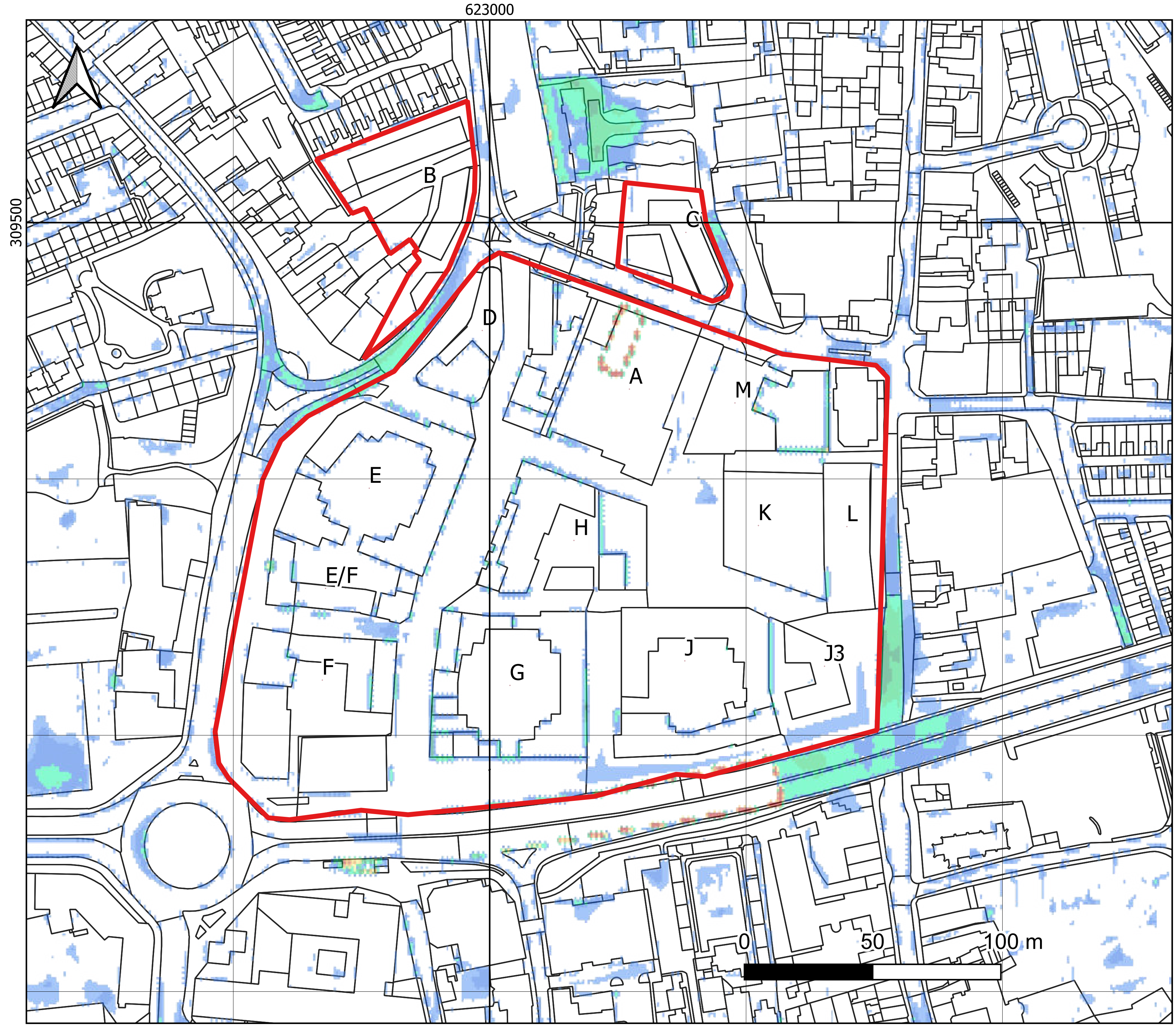


ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:100 Year plus 40% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Depth (m)

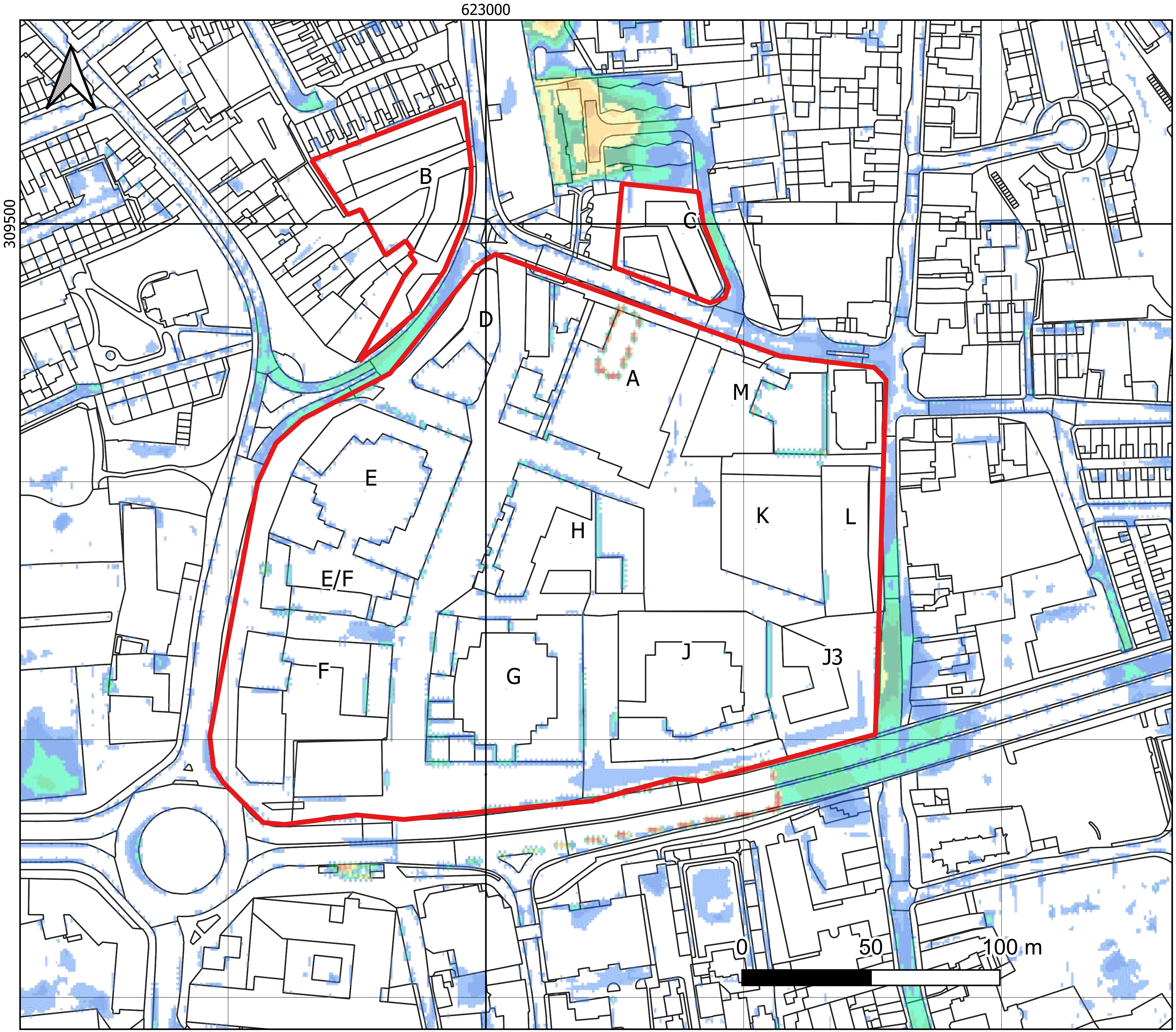
<= 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
> 1

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:30 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Depth (m)

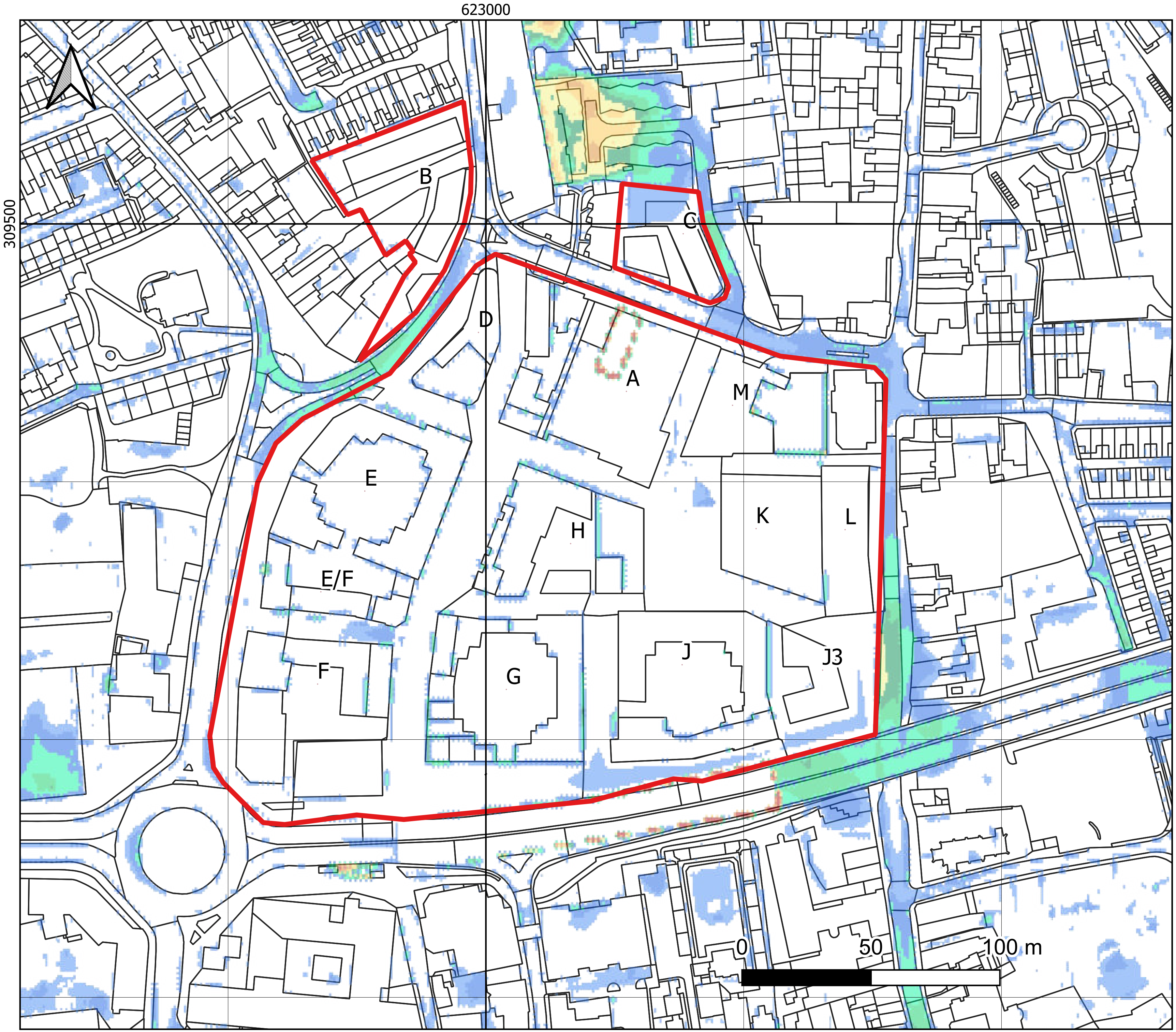
- <= 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1.0
- > 1

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:75 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Depth (m)

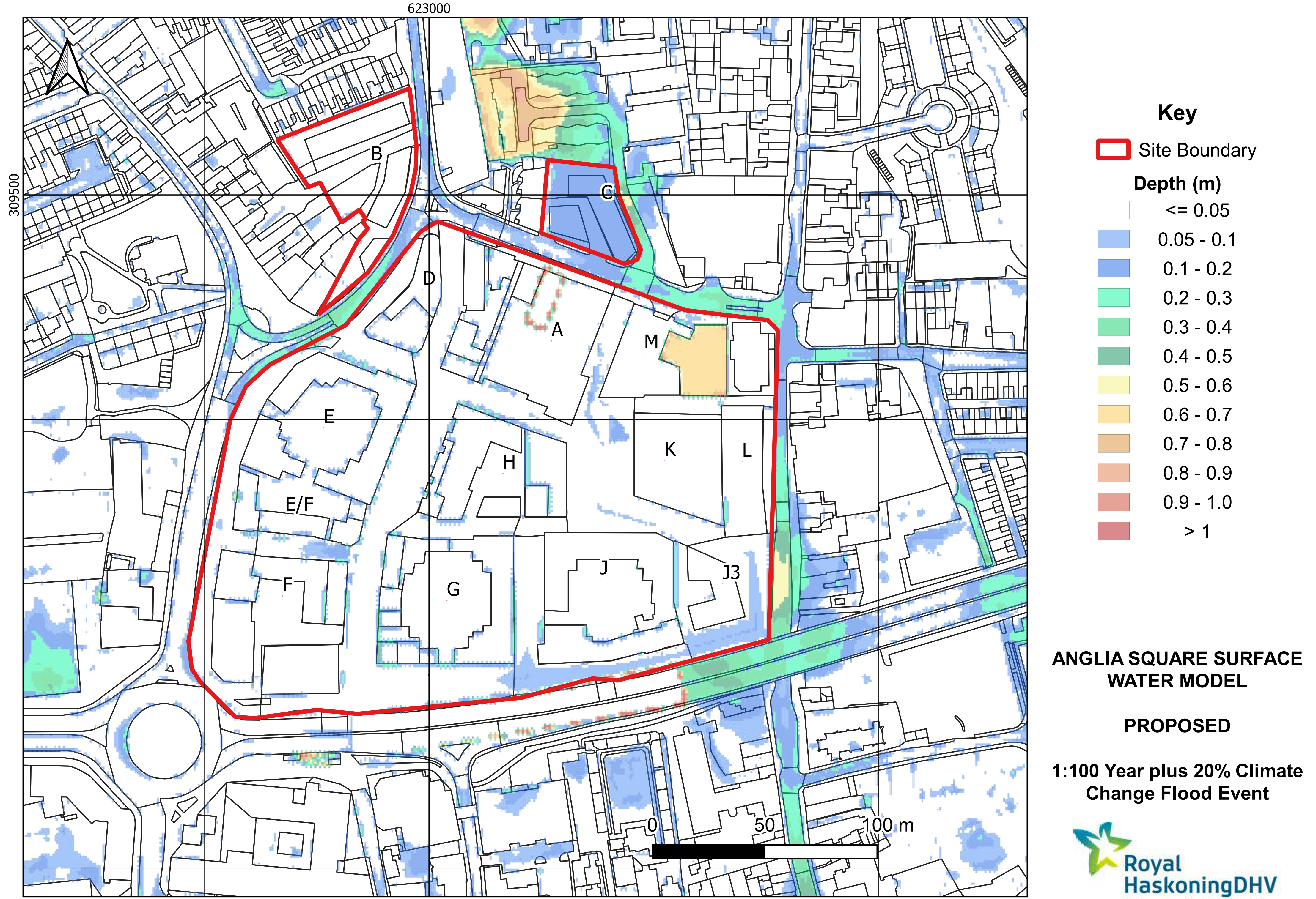
<= 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
> 1

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:100 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together

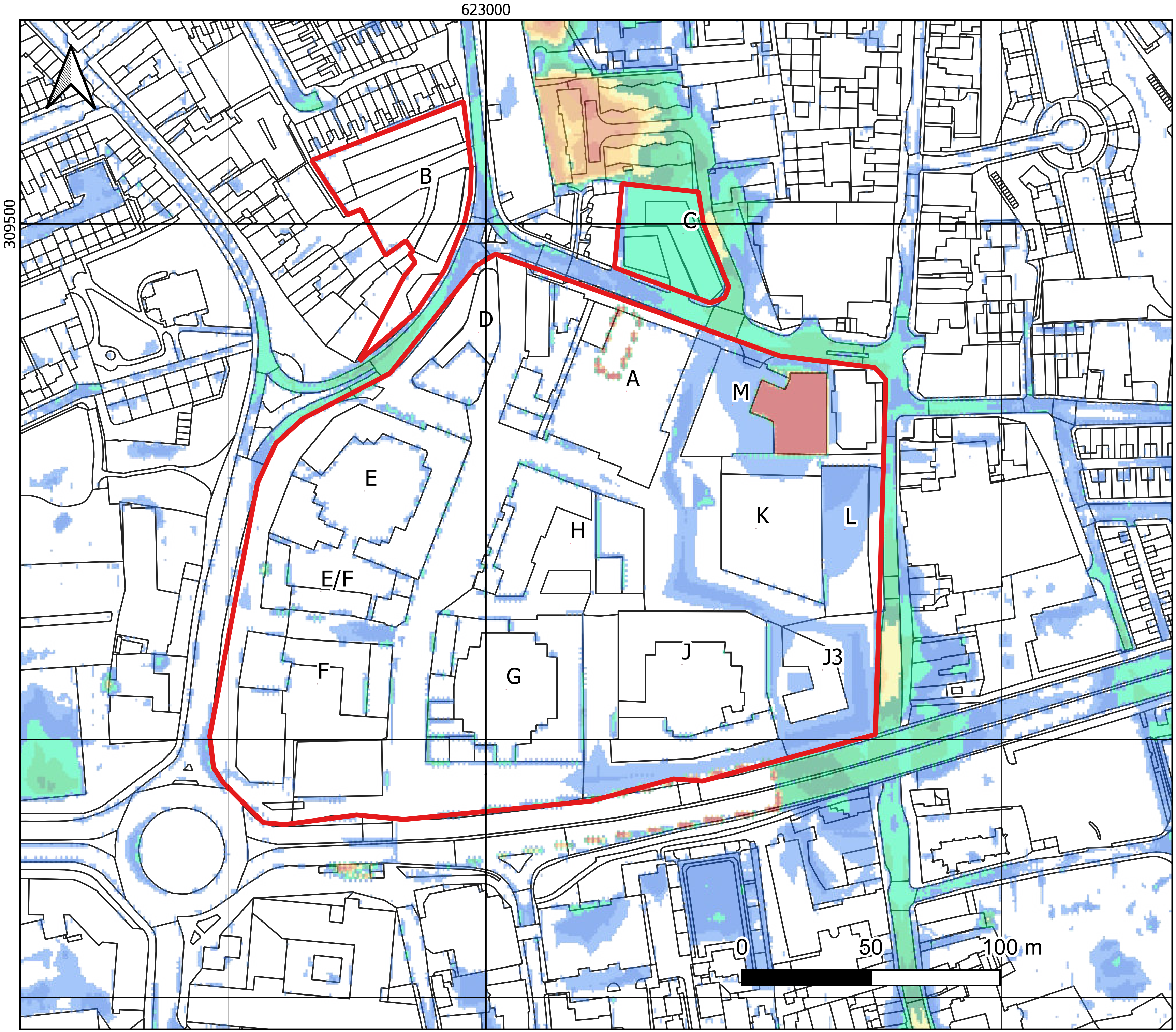


ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:100 Year plus 20% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Depth (m)

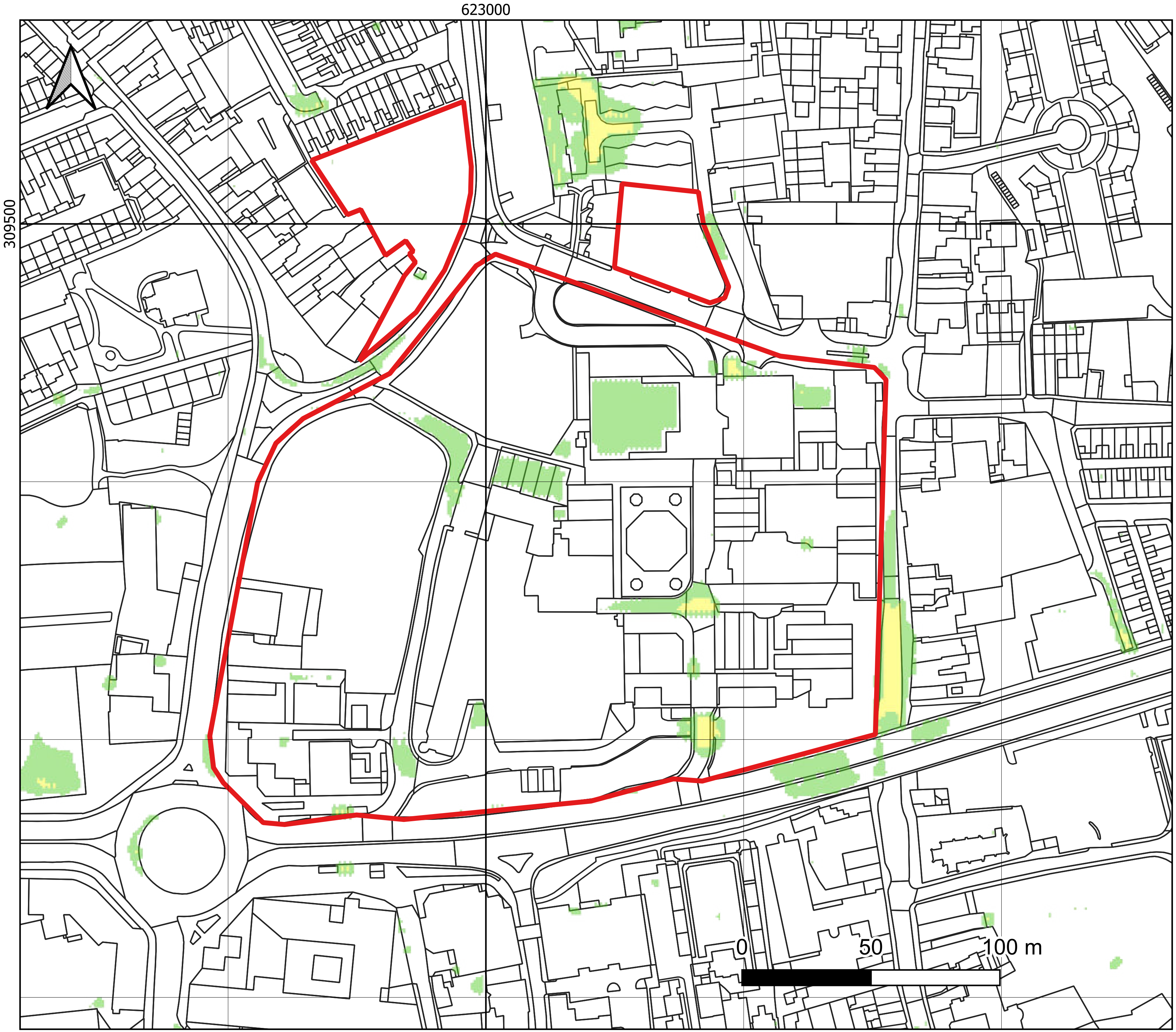
<= 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
> 1

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:100 Year plus 40% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Hazard Rating

<= 0.05

0.05 - 0.75 (Low)

0.75 - 1.25 (Moderate)

1.25 - 2 (Sigificant)

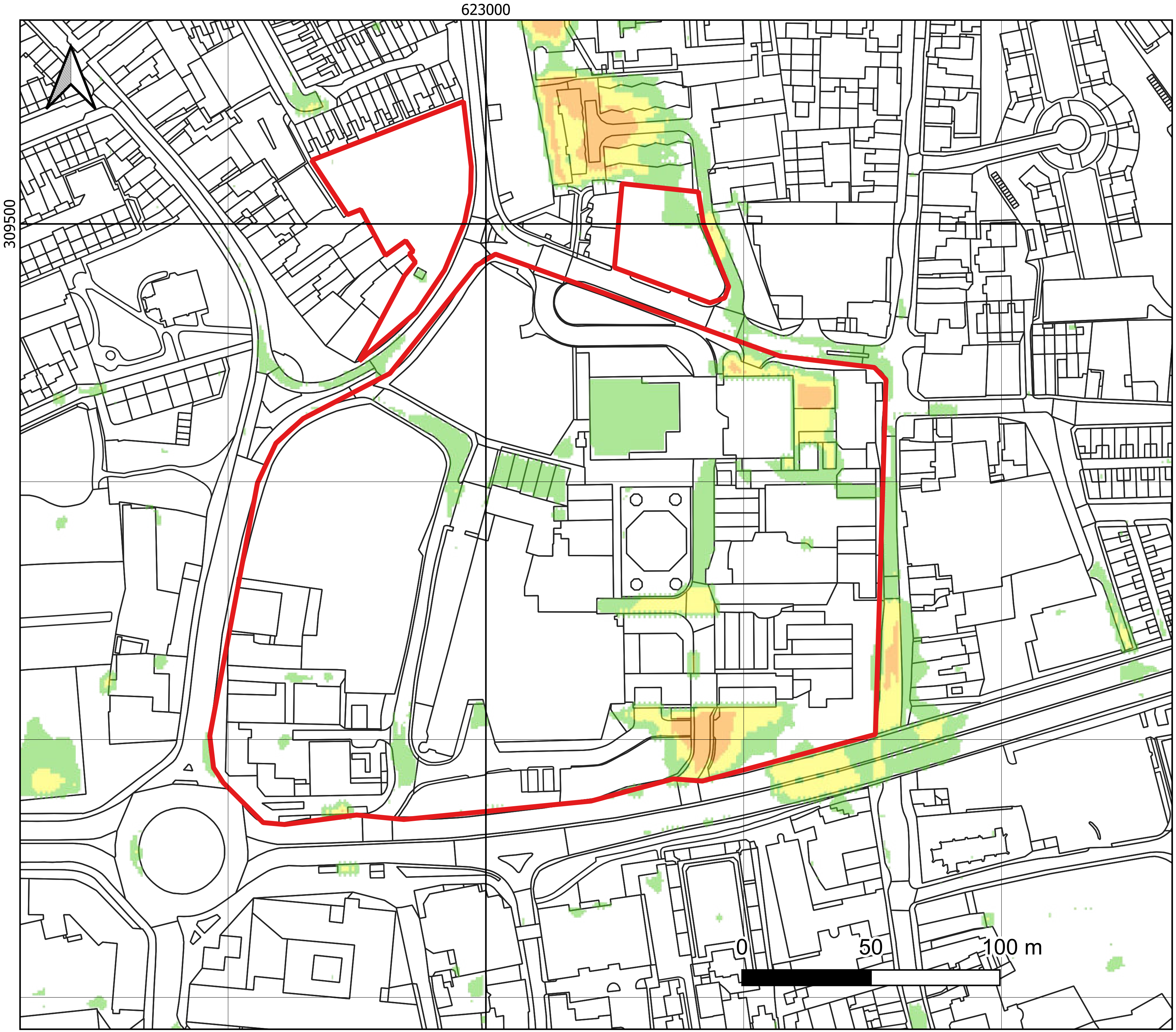
> 2 (Extreme)

ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:30 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Hazard Rating

	<= 0.05
	0.05 - 0.75 (Low)
	0.75 - 1.25 (Moderate)
	1.25 - 2 (Sigificant)
	> 2 (Extreme)

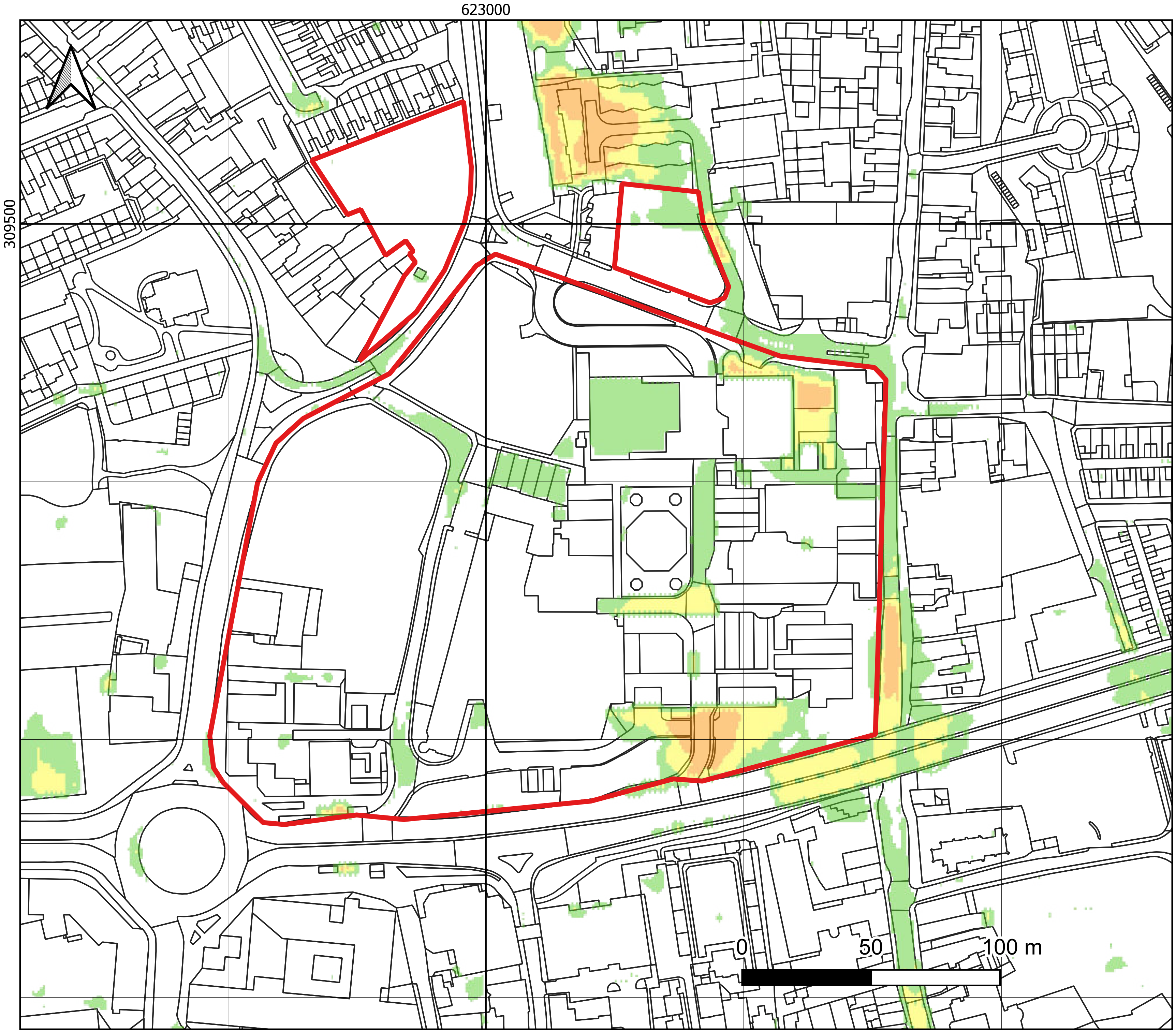
ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:75 Year Flood Event

Royal HaskoningDHV

Enhancing Society Together



Key

Site Boundary

Hazard Rating

<= 0.05

0.05 - 0.75 (Low)

0.75 - 1.25 (Moderate)

1.25 - 2 (Sigificant)

> 2 (Extreme)

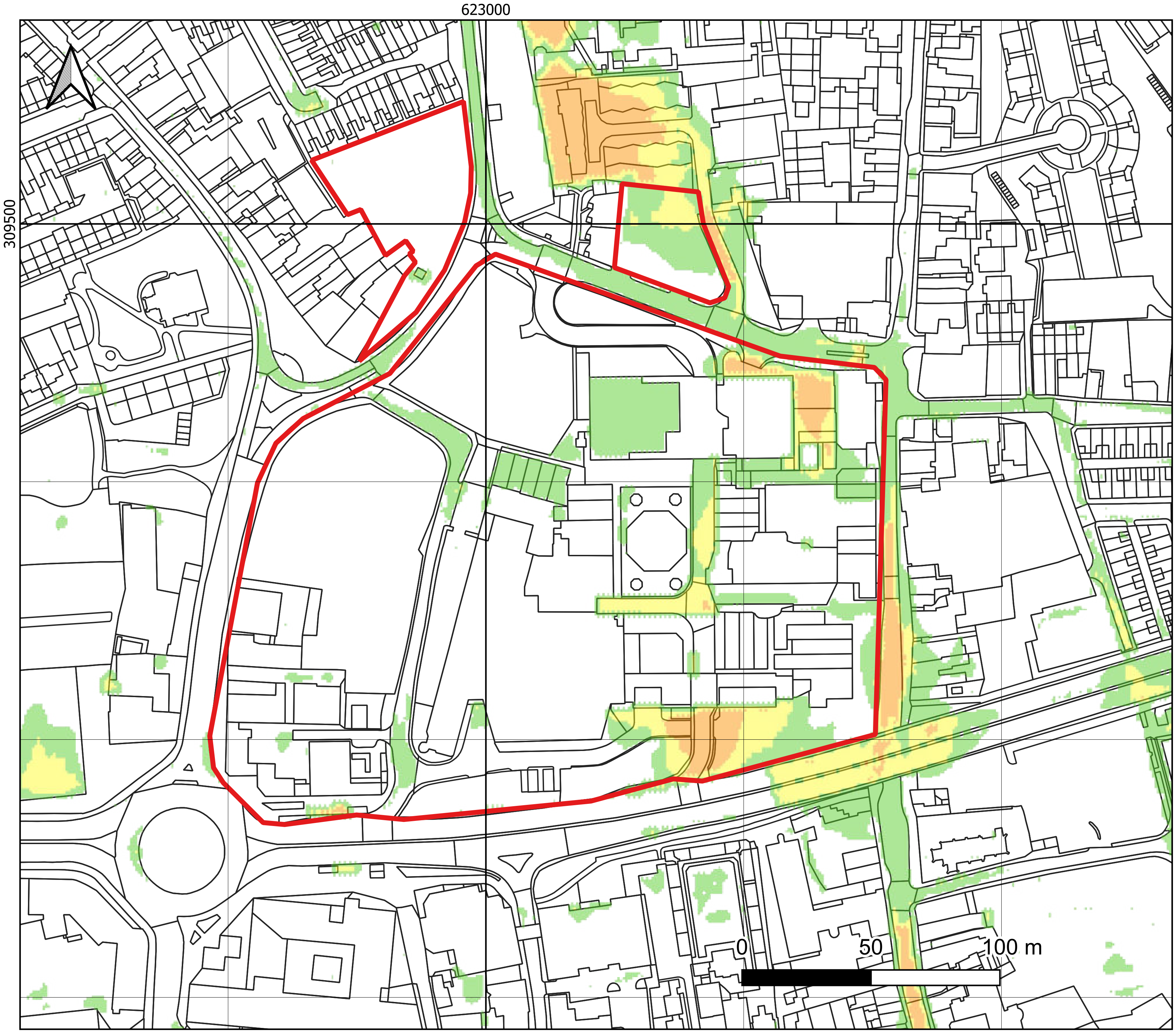
ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:100 Year Flood Event

Royal HaskoningDHV

Enhancing Society Together



Key

Site Boundary

Hazard Rating

<= 0.05

0.05 - 0.75 (Low)

0.75 - 1.25 (Moderate)

1.25 - 2 (Sigificant)

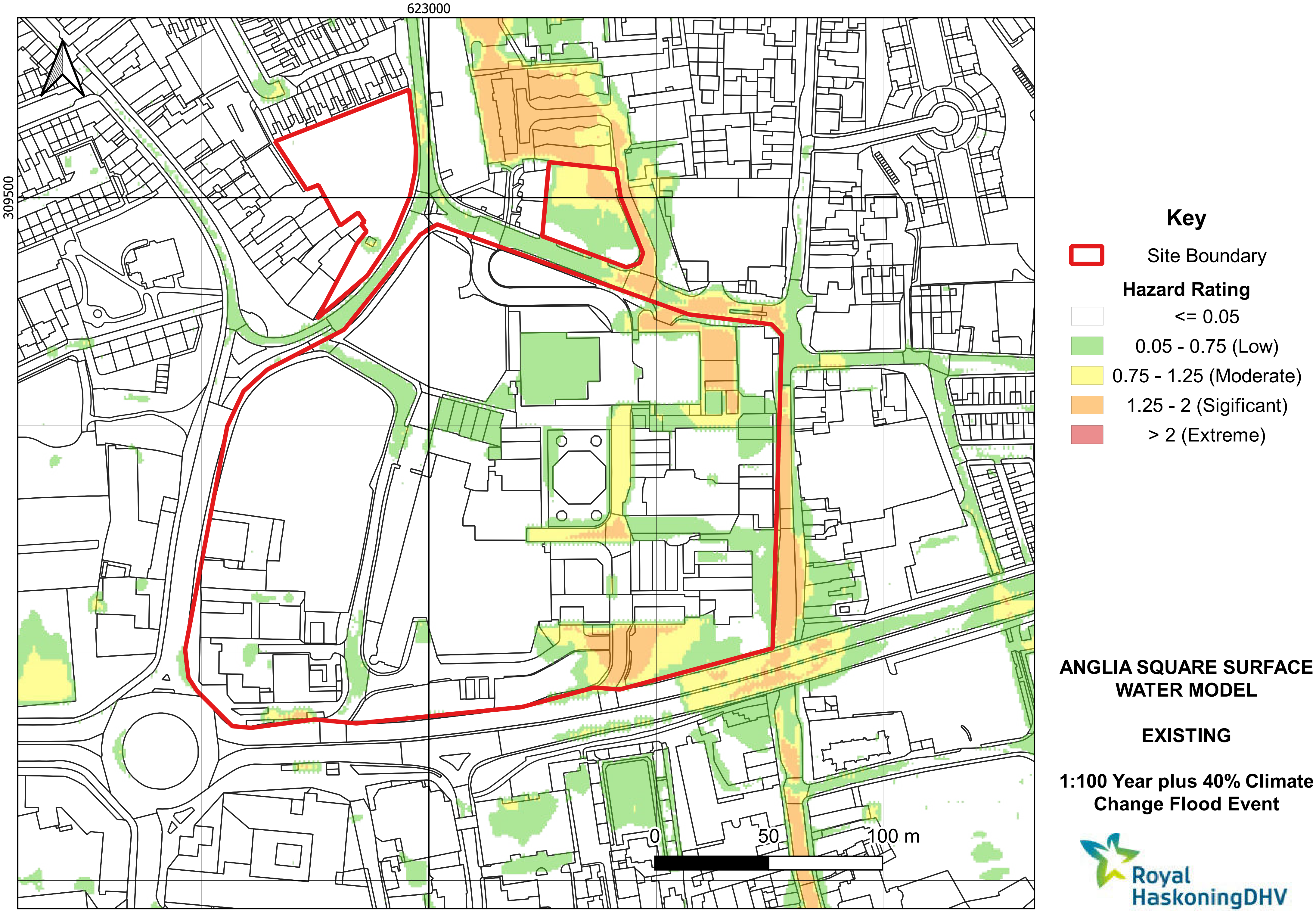
> 2 (Extreme)

ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:100 Year plus 20% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together

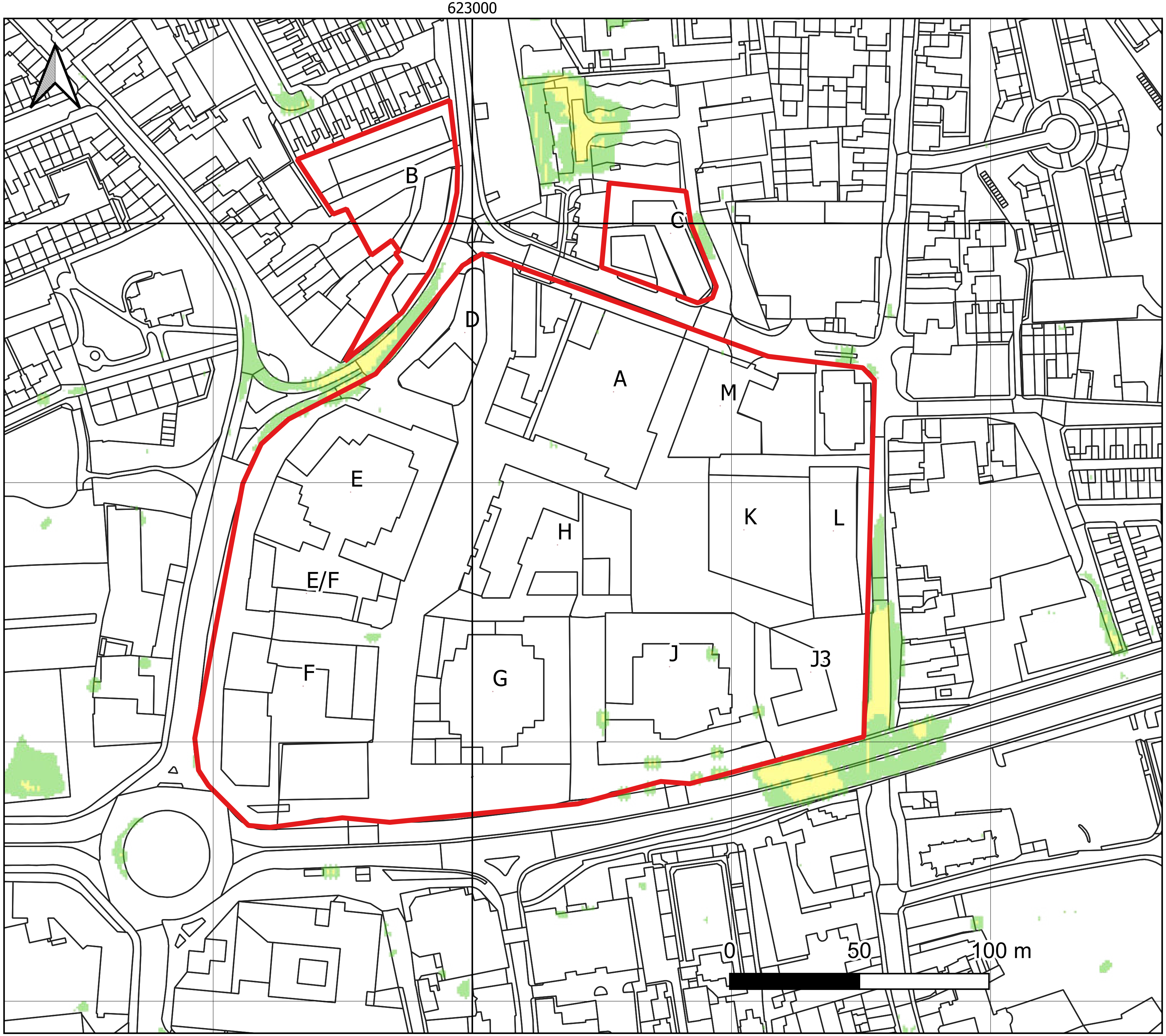


ANGLIA SQUARE SURFACE WATER MODEL

EXISTING

1:100 Year plus 40% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Hazard Rating

<= 0.05

0.05 - 0.75 (Low)

0.75 - 1.25 (Moderate)

1.25 - 2 (Sigificant)

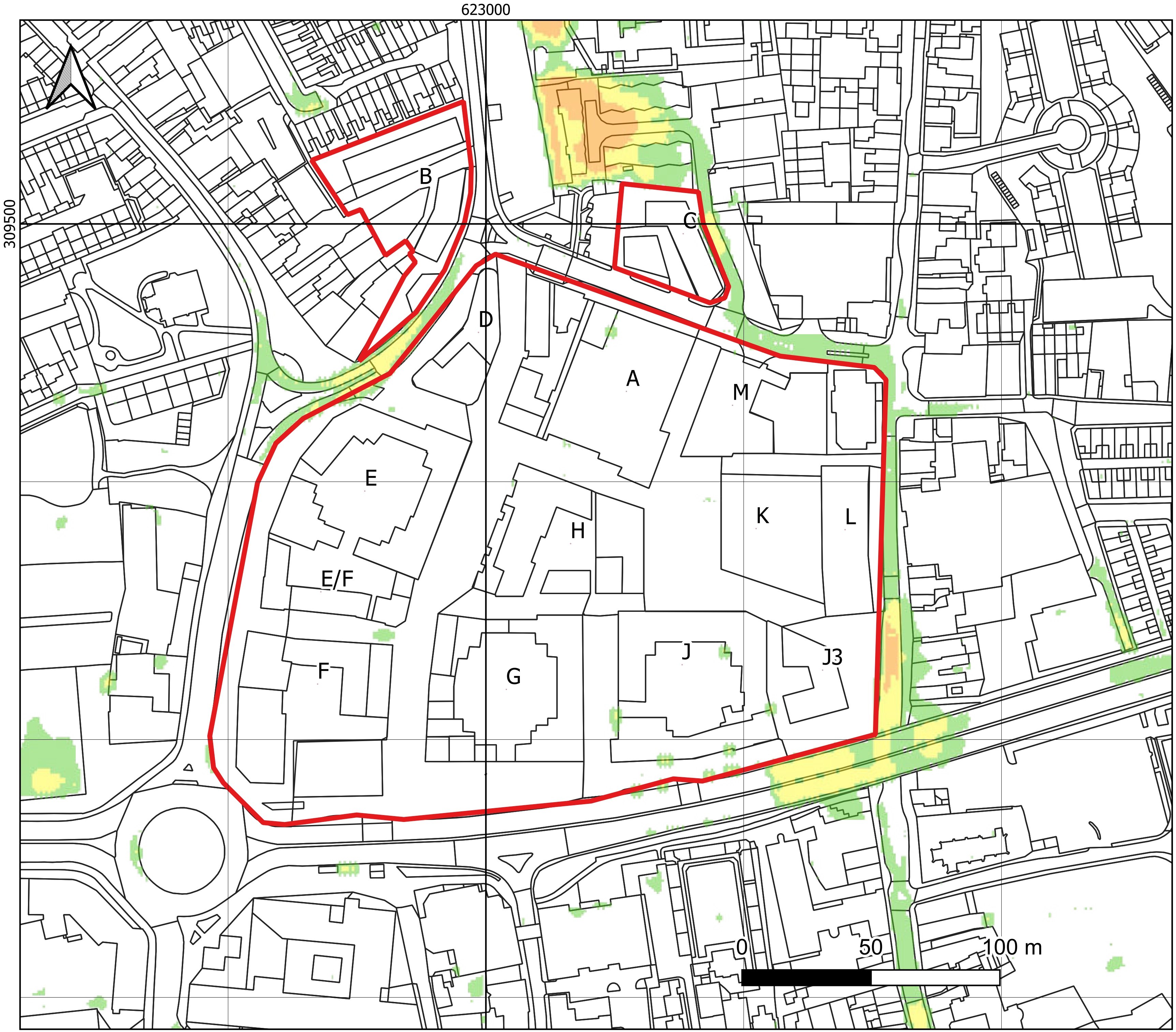
> 2 (Extreme)

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:30 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Hazard Rating

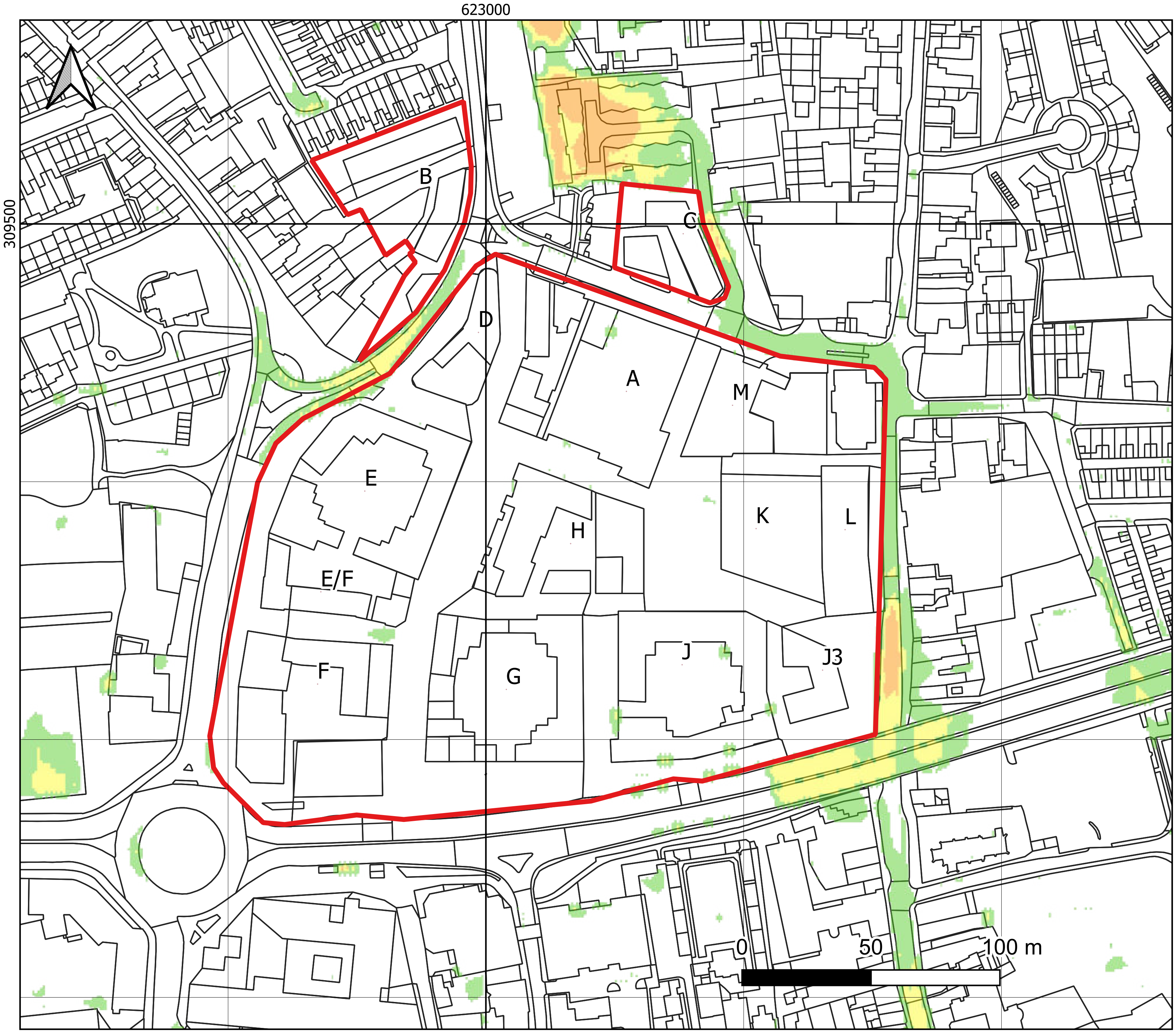
	Hazard Rating
White	<= 0.05
Green	0.05 - 0.75 (Low)
Yellow	0.75 - 1.25 (Moderate)
Orange	1.25 - 2 (Sigificant)
Red	> 2 (Extreme)

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:75 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Hazard Rating

<= 0.05

0.05 - 0.75 (Low)

0.75 - 1.25 (Moderate)

1.25 - 2 (Sigificant)

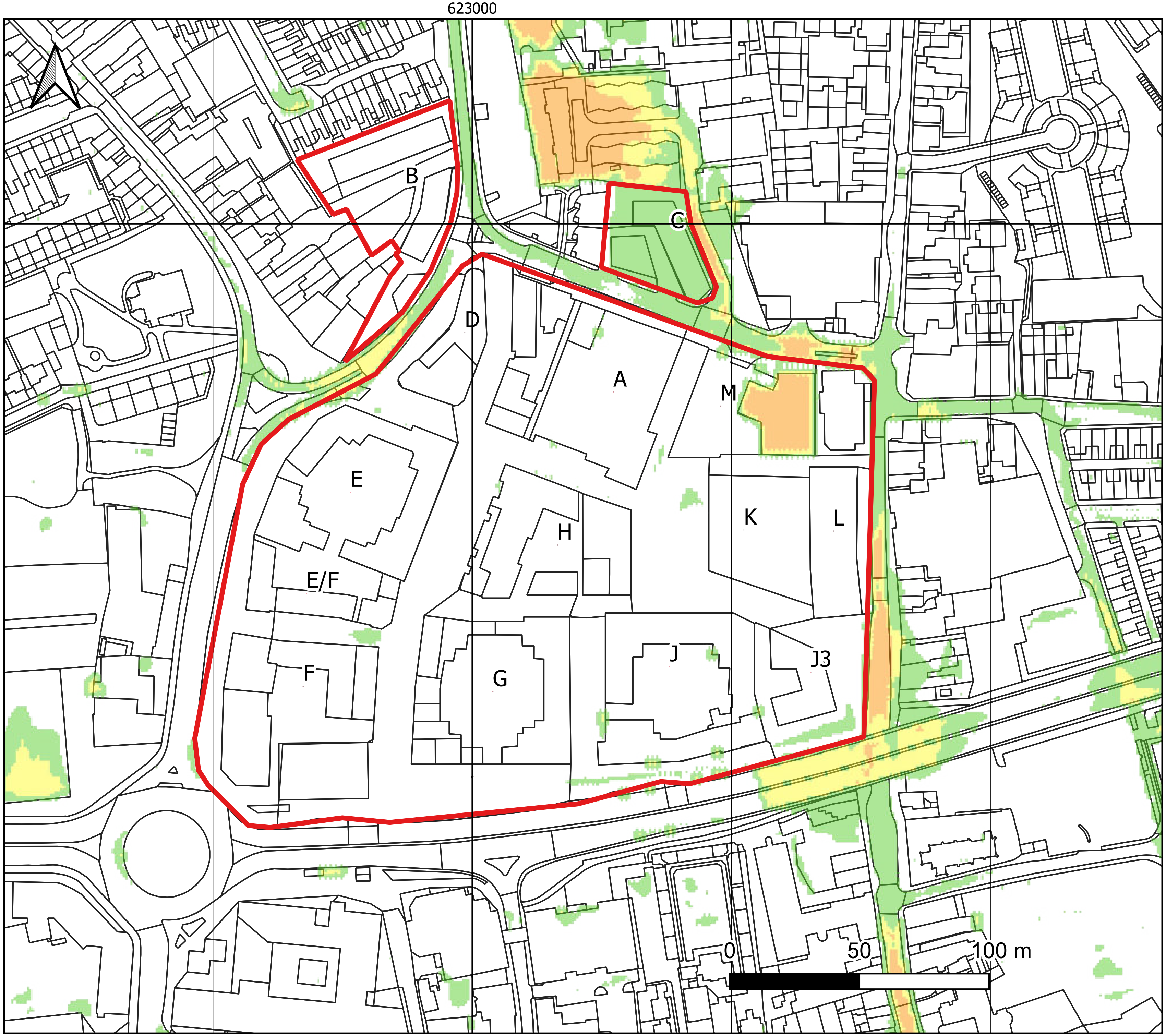
> 2 (Extreme)

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:100 Year Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Hazard Rating

<= 0.05

0.05 - 0.75 (Low)

0.75 - 1.25 (Moderate)

1.25 - 2 (Sigificant)

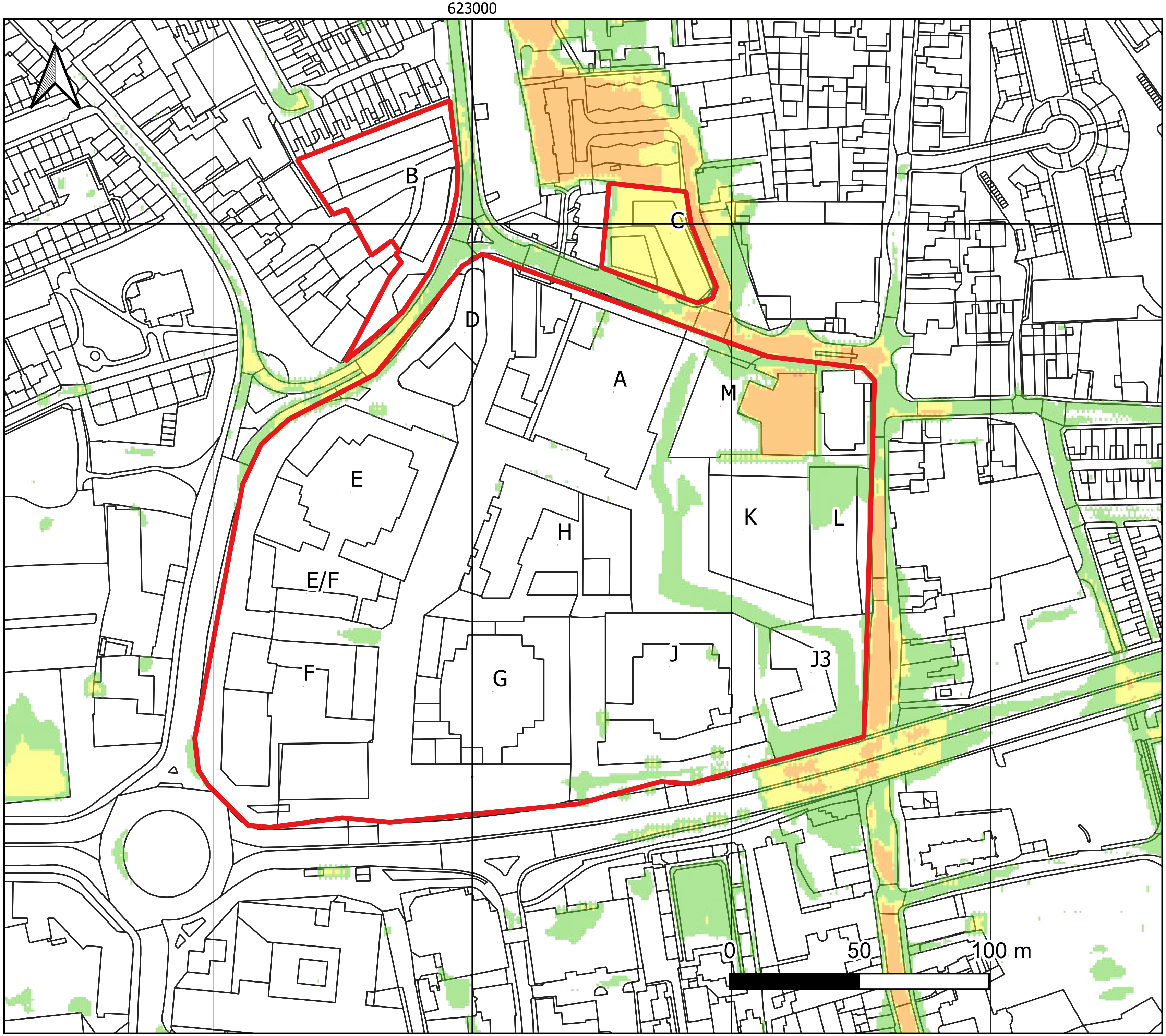
> 2 (Extreme)

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:100 Year plus 20% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together



Key

Site Boundary

Hazard Rating

	<= 0.05
	0.05 - 0.75 (Low)
	0.75 - 1.25 (Moderate)
	1.25 - 2 (Sigificant)
	> 2 (Extreme)

ANGLIA SQUARE SURFACE WATER MODEL

PROPOSED

1:100 Year plus 40% Climate Change Flood Event

Royal HaskoningDHV
Enhancing Society Together

Appendix C: TLF File Summary

Anglia_Square_Existing_P0030_3hr_SM_013
Model Parameters & Statistics

BUILD SETTINGS

TUFLOW Engine = 2020-10-AA-iSP-w64
HPC Build = 2.16.

TEMPORAL SETTINGS

1D Timestep (s) = 1D Timestep not found
2D Timestep (s) = 1.000
Start Time (hrs) = 0.000
Finish Time (hrs) = 6.00

GRID SETTINGS

Cell Size (m) = 2
Grid Size (m) = 2475,2025
Grid Origin (British Grid) = 621219.427 308687.061
Grid Rotation (degrees) = 0.000000

BOUNDARIES

Number of HS Boundaries = 0
Number of HT Boundaries = 0
Number of HQ Boundaries = 0

Number of QC Boundaries = 0
Number of QT Boundaries = 0
Number of QH Boundaries = 0

1D STRUCTURES

Number of Normal (Blank) Channels = 0
Number of B (Bridge) Structures = 0
Number of BB (Bridge) Structures = 0
Number of C (Circular) Culverts = 0
Number of G (Gradient) Channels = 0
Number of I (Irregular) Culverts = 0
Number of M (hQh Matrix) Channels = 0
Number of N (Non-Inertial) Channels = 0
Number of O (Operated) Structures = 0
Number of P (Pump) Channels = 0
Number of Q (Depth-Discharge) Channels = 0
Number of Q (Depth-Discharge) Pits = 0
Number of VPI Virtual Pipe Inlet Pits = 0
Number of VPO Virtual Pipe Outlet Pits = 0

Number of R (Rectangular) Structures = 1
Number of RG (Radial Gate) Structures = 0
Number of S (Sloping Open) Channels = 0
Number of SG (Sluice Gate) Structures = 0
Number of SP (Spillway) Structures = 0
Number of W (Original Weir) Structures = 0
Number of WB (Broad-crested Weirs)= 0
Number of WC (Crump Weirs)= 0
Number of WD (User-defined Weirs)= 0
Number of WO (Ogee-crested Weirs)= 0
Number of WR (Rectangular Weirs)= 0
Number of WT (Trapezoidal Weirs)= 0
Number of WV (V-Notch Weirs)= 0
Number of WW (Standard Weirs)= 0

WARNINGS AND CHECKS

Number of 1D Negative Depths = 0
Number of 2D Negative Depths = 0

Number of Prior Warnings = 16
Number of Prior Checks = 0
Number of Post Warnings = 85
Number of Post Checks = 0

OUTPUT STATS

Start Volume (m^3) = 0
End Volume (m^3) = 75535
Volume In (m^3) = 86259
Volume Out (m^3) = 10728
Volume Error (m^3) = 4 or -0.0% of Volume In + Out
Final Cumulative Mass Error = -0.00%
Peak Cumulative Mass Error = 0.10%

Anglia_Square_Existing_P0075_3hr_SM_013
Model Parameters & Statistics

Royal HaskoningDHV

BUILD SETTINGS

TUFLOW Engine = 2020-10-AA-iSP-w64
HPC Build = 2.16.

TEMPORAL SETTINGS

1D Timestep (s) = 1D Timestep not found
2D Timestep (s) = 1.000
Start Time (hrs) = 0.000
Finish Time (hrs) = 6.00

GRID SETTINGS

Cell Size (m) = 2
Grid Size (m) = 2475,2025
Grid Origin (British Grid) = 621219.427 308687.061
Grid Rotation (degrees) = 0.000000

BOUNDARIES

Number of HS Boundaries = 0
Number of HT Boundaries = 0
Number of HQ Boundaries = 0

Number of QC Boundaries = 0
Number of QT Boundaries = 0
Number of QH Boundaries = 0

1D STRUCTURES

Number of Normal (Blank) Channels = 0
Number of B (Bridge) Structures = 0
Number of BB (Bridge) Structures = 0
Number of C (Circular) Culverts = 0
Number of G (Gradient) Channels = 0
Number of I (Irregular) Culverts = 0
Number of M (hQh Matrix) Channels = 0
Number of N (Non-Inertial) Channels = 0
Number of O (Operated) Structures = 0
Number of P (Pump) Channels = 0
Number of Q (Depth-Discharge) Channels = 0
Number of Q (Depth-Discharge) Pits = 0
Number of VPI Virtual Pipe Inlet Pits = 0
Number of VPO Virtual Pipe Outlet Pits = 0

Number of R (Rectangular) Structures = 1
Number of RG (Radial Gate) Structures = 0
Number of S (Sloping Open) Channels = 0
Number of SG (Sluice Gate) Structures = 0
Number of SP (Spillway) Structures = 0
Number of W (Original Weir) Structures = 0
Number of WB (Broad-crested Weirs)= 0
Number of WC (Crump Weirs)= 0
Number of WD (User-defined Weirs)= 0
Number of WO (Ogee-crested Weirs)= 0
Number of WR (Rectangular Weirs)= 0
Number of WT (Trapezoidal Weirs)= 0
Number of WV (V-Notch Weirs)= 0
Number of WW (Standard Weirs)= 0

WARNINGS AND CHECKS

Number of 1D Negative Depths = 0
Number of 2D Negative Depths = 0

Number of Prior Warnings = 16
Number of Prior Checks = 0
Number of Post Warnings = 21
Number of Post Checks = 0

OUTPUT STATS

Start Volume (m^3) = 0
End Volume (m^3) = 96049
Volume In (m^3) = 117420
Volume Out (m^3) = 21406
Volume Error (m^3) = 34 or -0.0% of Volume In + Out
Final Cumulative Mass Error = -0.02%
Peak Cumulative Mass Error = 0.02%

Anglia_Square_Existing_P0100_3hr_SM_013
Model Parameters & Statistics

BUILD SETTINGS

TUFLOW Engine = 2020-10-AA-iSP-w64
HPC Build = 2.16.

TEMPORAL SETTINGS

1D Timestep (s) = 1D Timestep not found
2D Timestep (s) = 1.000
Start Time (hrs) = 0.000
Finish Time (hrs) = 6.00

GRID SETTINGS

Cell Size (m) = 2
Grid Size (m) = 2475,2025
Grid Origin (British Grid) = 621219.427 308687.061
Grid Rotation (degrees) = 0.000000

BOUNDARIES

Number of HS Boundaries = 0
Number of HT Boundaries = 0
Number of HQ Boundaries = 0

Number of QC Boundaries = 0
Number of QT Boundaries = 0
Number of QH Boundaries = 0

1D STRUCTURES

Number of Normal (Blank) Channels = 0
Number of B (Bridge) Structures = 0
Number of BB (Bridge) Structures = 0
Number of C (Circular) Culverts = 0
Number of G (Gradient) Channels = 0
Number of I (Irregular) Culverts = 0
Number of M (hQh Matrix) Channels = 0
Number of N (Non-Inertial) Channels = 0
Number of O (Operated) Structures = 0
Number of P (Pump) Channels = 0
Number of Q (Depth-Discharge) Channels = 0
Number of Q (Depth-Discharge) Pits = 0
Number of VPI Virtual Pipe Inlet Pits = 0
Number of VPO Virtual Pipe Outlet Pits = 0

Number of R (Rectangular) Structures = 1
Number of RG (Radial Gate) Structures = 0
Number of S (Sloping Open) Channels = 0
Number of SG (Sluice Gate) Structures = 0
Number of SP (Spillway) Structures = 0
Number of W (Original Weir) Structures = 0
Number of WB (Broad-crested Weirs)= 0
Number of WC (Crump Weirs)= 0
Number of WD (User-defined Weirs)= 0
Number of WO (Ogee-crested Weirs)= 0
Number of WR (Rectangular Weirs)= 0
Number of WT (Trapezoidal Weirs)= 0
Number of WV (V-Notch Weirs)= 0
Number of WW (Standard Weirs)= 0

WARNINGS AND CHECKS

Number of 1D Negative Depths = 0
Number of 2D Negative Depths = 0

Number of Prior Warnings = 16
Number of Prior Checks = 0
Number of Post Warnings = 5
Number of Post Checks = 0

OUTPUT STATS

Start Volume (m^3) = 0
End Volume (m^3) = 103798
Volume In (m^3) = 129665
Volume Out (m^3) = 25871
Volume Error (m^3) = 5 or -0.0% of Volume In + Out
Final Cumulative Mass Error = -0.00%
Peak Cumulative Mass Error = 0.00%

Anglia_Square_Existing_P0100_40CC_3hr_SM_013
Model Parameters & Statistics

BUILD SETTINGS

TUFLOW Engine = 2020-10-AA-iSP-w64
HPC Build = 2.16.

TEMPORAL SETTINGS

1D Timestep (s) = 1D Timestep not found
2D Timestep (s) = 1.000
Start Time (hrs) = 0.000
Finish Time (hrs) = 6.00

GRID SETTINGS

Cell Size (m) = 2
Grid Size (m) = 2475,2025
Grid Origin (British Grid) = 621219.427 308687.061
Grid Rotation (degrees) = 0.000000

BOUNDARIES

Number of HS Boundaries = 0
Number of HT Boundaries = 0
Number of HQ Boundaries = 0

Number of QC Boundaries = 0
Number of QT Boundaries = 0
Number of QH Boundaries = 0

1D STRUCTURES

Number of Normal (Blank) Channels = 0
Number of B (Bridge) Structures = 0
Number of BB (Bridge) Structures = 0
Number of C (Circular) Culverts = 0
Number of G (Gradient) Channels = 0
Number of I (Irregular) Culverts = 0
Number of M (hQh Matrix) Channels = 0
Number of N (Non-Inertial) Channels = 0
Number of O (Operated) Structures = 0
Number of P (Pump) Channels = 0
Number of Q (Depth-Discharge) Channels = 0
Number of Q (Depth-Discharge) Pits = 0
Number of VPI Virtual Pipe Inlet Pits = 0
Number of VPO Virtual Pipe Outlet Pits = 0

Number of R (Rectangular) Structures = 1
Number of RG (Radial Gate) Structures = 0
Number of S (Sloping Open) Channels = 0
Number of SG (Sluice Gate) Structures = 0
Number of SP (Spillway) Structures = 0
Number of W (Original Weir) Structures = 0
Number of WB (Broad-crested Weirs)= 0
Number of WC (Crump Weirs)= 0
Number of WD (User-defined Weirs)= 0
Number of WO (Ogee-crested Weirs)= 0
Number of WR (Rectangular Weirs)= 0
Number of WT (Trapezoidal Weirs)= 0
Number of WV (V-Notch Weirs)= 0
Number of WW (Standard Weirs)= 0

WARNINGS AND CHECKS

Number of 1D Negative Depths = 0
Number of 2D Negative Depths = 0

Number of Prior Warnings = 16
Number of Prior Checks = 0
Number of Post Warnings = 4
Number of Post Checks = 0

OUTPUT STATS

Start Volume (m^3) = 0
End Volume (m^3) = 129027
Volume In (m^3) = 209310
Volume Out (m^3) = 80382
Volume Error (m^3) = 98 or -0.0% of Volume In + Out
Final Cumulative Mass Error = 0.03%
Peak Cumulative Mass Error = 0.04%

Anglia_Square_Proposed_P0030_3hr_SM_013
Model Parameters & Statistics

BUILD SETTINGS

TUFLOW Engine = 2020-10-AA-iSP-w64
HPC Build = 2.16.

TEMPORAL SETTINGS

1D Timestep (s) = 1D Timestep not found
2D Timestep (s) = 1.000
Start Time (hrs) = 0.000
Finish Time (hrs) = 6.00

GRID SETTINGS

Cell Size (m) = 2
Grid Size (m) = 2475,2025
Grid Origin (British Grid) = 621219.427 308687.061
Grid Rotation (degrees) = 0.000000

BOUNDARIES

Number of HS Boundaries = 0
Number of HT Boundaries = 0
Number of HQ Boundaries = 0

Number of QC Boundaries = 0
Number of QT Boundaries = 0
Number of QH Boundaries = 0

1D STRUCTURES

Number of Normal (Blank) Channels = 0
Number of B (Bridge) Structures = 0
Number of BB (Bridge) Structures = 0
Number of C (Circular) Culverts = 0
Number of G (Gradient) Channels = 0
Number of I (Irregular) Culverts = 0
Number of M (hQh Matrix) Channels = 0
Number of N (Non-Inertial) Channels = 0
Number of O (Operated) Structures = 0
Number of P (Pump) Channels = 0
Number of Q (Depth-Discharge) Channels = 0
Number of Q (Depth-Discharge) Pits = 0
Number of VPI Virtual Pipe Inlet Pits = 0
Number of VPO Virtual Pipe Outlet Pits = 0

Number of R (Rectangular) Structures = 1
Number of RG (Radial Gate) Structures = 0
Number of S (Sloping Open) Channels = 0
Number of SG (Sluice Gate) Structures = 0
Number of SP (Spillway) Structures = 0
Number of W (Original Weir) Structures = 0
Number of WB (Broad-crested Weirs)= 0
Number of WC (Crump Weirs)= 0
Number of WD (User-defined Weirs)= 0
Number of WO (Ogee-crested Weirs)= 0
Number of WR (Rectangular Weirs)= 0
Number of WT (Trapezoidal Weirs)= 0
Number of WV (V-Notch Weirs)= 0
Number of WW (Standard Weirs)= 0

WARNINGS AND CHECKS

Number of 1D Negative Depths = 0
Number of 2D Negative Depths = 0

Number of Prior Warnings = 49
Number of Prior Checks = 0
Number of Post Warnings = 85
Number of Post Checks = 0

OUTPUT STATS

Start Volume (m^3) = 0
End Volume (m^3) = 75534
Volume In (m^3) = 86260
Volume Out (m^3) = 10730
Volume Error (m^3) = 4 or -0.0% of Volume In + Out
Final Cumulative Mass Error = 0.00%
Peak Cumulative Mass Error = 0.10%

Anglia_Square_Proposed_P0075_3hr_SM_013
Model Parameters & Statistics

BUILD SETTINGS

TUFLOW Engine = 2020-10-AA-iSP-w64
HPC Build = 2.16.

TEMPORAL SETTINGS

1D Timestep (s) = 1D Timestep not found
2D Timestep (s) = 1.000
Start Time (hrs) = 0.000
Finish Time (hrs) = 6.00

GRID SETTINGS

Cell Size (m) = 2
Grid Size (m) = 2475,2025
Grid Origin (British Grid) = 621219.427 308687.061
Grid Rotation (degrees) = 0.000000

BOUNDARIES

Number of HS Boundaries = 0
Number of HT Boundaries = 0
Number of HQ Boundaries = 0

Number of QC Boundaries = 0
Number of QT Boundaries = 0
Number of QH Boundaries = 0

1D STRUCTURES

Number of Normal (Blank) Channels = 0
Number of B (Bridge) Structures = 0
Number of BB (Bridge) Structures = 0
Number of C (Circular) Culverts = 0
Number of G (Gradient) Channels = 0
Number of I (Irregular) Culverts = 0
Number of M (hQh Matrix) Channels = 0
Number of N (Non-Inertial) Channels = 0
Number of O (Operated) Structures = 0
Number of P (Pump) Channels = 0
Number of Q (Depth-Discharge) Channels = 0
Number of Q (Depth-Discharge) Pits = 0
Number of VPI Virtual Pipe Inlet Pits = 0
Number of VPO Virtual Pipe Outlet Pits = 0

Number of R (Rectangular) Structures = 1
Number of RG (Radial Gate) Structures = 0
Number of S (Sloping Open) Channels = 0
Number of SG (Sluice Gate) Structures = 0
Number of SP (Spillway) Structures = 0
Number of W (Original Weir) Structures = 0
Number of WB (Broad-crested Weirs)= 0
Number of WC (Crump Weirs)= 0
Number of WD (User-defined Weirs)= 0
Number of WO (Ogee-crested Weirs)= 0
Number of WR (Rectangular Weirs)= 0
Number of WT (Trapezoidal Weirs)= 0
Number of WV (V-Notch Weirs)= 0
Number of WW (Standard Weirs)= 0

WARNINGS AND CHECKS

Number of 1D Negative Depths = 0
Number of 2D Negative Depths = 0

Number of Prior Warnings = 49
Number of Prior Checks = 0
Number of Post Warnings = 20
Number of Post Checks = 0

OUTPUT STATS

Start Volume (m^3) = 0
End Volume (m^3) = 96048
Volume In (m^3) = 117417
Volume Out (m^3) = 21407
Volume Error (m^3) = 38 or -0.0% of Volume In + Out
Final Cumulative Mass Error = 0.03%
Peak Cumulative Mass Error = 0.02%

Anglia_Square_Proposed_P0100_3hr_SM_013
Model Parameters & Statistics

BUILD SETTINGS

TUFLOW Engine = 2020-10-AA-iSP-w64
HPC Build = 2.16.

TEMPORAL SETTINGS

1D Timestep (s) = 1D Timestep not found
2D Timestep (s) = 1.000
Start Time (hrs) = 0.000
Finish Time (hrs) = 6.00

GRID SETTINGS

Cell Size (m) = 2
Grid Size (m) = 2475,2025
Grid Origin (British Grid) = 621219.427 308687.061
Grid Rotation (degrees) = 0.000000

BOUNDARIES

Number of HS Boundaries = 0
Number of HT Boundaries = 0
Number of HQ Boundaries = 0

Number of QC Boundaries = 0
Number of QT Boundaries = 0
Number of QH Boundaries = 0

1D STRUCTURES

Number of Normal (Blank) Channels = 0
Number of B (Bridge) Structures = 0
Number of BB (Bridge) Structures = 0
Number of C (Circular) Culverts = 0
Number of G (Gradient) Channels = 0
Number of I (Irregular) Culverts = 0
Number of M (hQh Matrix) Channels = 0
Number of N (Non-Inertial) Channels = 0
Number of O (Operated) Structures = 0
Number of P (Pump) Channels = 0
Number of Q (Depth-Discharge) Channels = 0
Number of Q (Depth-Discharge) Pits = 0
Number of VPI Virtual Pipe Inlet Pits = 0
Number of VPO Virtual Pipe Outlet Pits = 0

Number of R (Rectangular) Structures = 1
Number of RG (Radial Gate) Structures = 0
Number of S (Sloping Open) Channels = 0
Number of SG (Sluice Gate) Structures = 0
Number of SP (Spillway) Structures = 0
Number of W (Original Weir) Structures = 0
Number of WB (Broad-crested Weirs)= 0
Number of WC (Crump Weirs)= 0
Number of WD (User-defined Weirs)= 0
Number of WO (Ogee-crested Weirs)= 0
Number of WR (Rectangular Weirs)= 0
Number of WT (Trapezoidal Weirs)= 0
Number of WV (V-Notch Weirs)= 0
Number of WW (Standard Weirs)= 0

WARNINGS AND CHECKS

Number of 1D Negative Depths = 0
Number of 2D Negative Depths = 0

Number of Prior Warnings = 49
Number of Prior Checks = 0
Number of Post Warnings = 5
Number of Post Checks = 0

OUTPUT STATS

Start Volume (m^3) = 0
End Volume (m^3) = 103386
Volume In (m^3) = 129659
Volume Out (m^3) = 26285
Volume Error (m^3) = 12 or -0.0% of Volume In + Out
Final Cumulative Mass Error = 0.01%
Peak Cumulative Mass Error = 0.01%