Newbuildings Farm
Flood Mapping Study

Hydraulics and Hydrology Technical Note

December 2012

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1 Introduction

1.1 Background

Lutra Consulting were commissioned by THDA Ltd Consulting Engineers to undertake a flood risk mapping study for Marston Brook and Kingston Brook located north of Stafford, Staffordshire.

At present, the Environment Agency's flood risk maps of the study area are based on a coarse model and historical events.

The aim of this study is to update the flood zones within the client's land. The primary source of flooding is assumed to be fluvial flow from the main watercourses. This study does not consider other sources of flooding (i.e. ground water, surface water).

This study has been carried out by adopting a similar methodology to the existing and latest Environment Agency flood model of the Sandyford Brook.

1.2 Site location

The site consists of 2 parcels of land situated to the north of Stafford, Staffordshire. Figure 1 shows location of the site. A small drainage ditch (Marston Brook tributary) runs through the site flowing in parallel to Marston Brook.

Site 1 is bound to the south by the A513, Marston Brook to the west and farms to the east and north. Site 2 is located to the south west of Hopton.

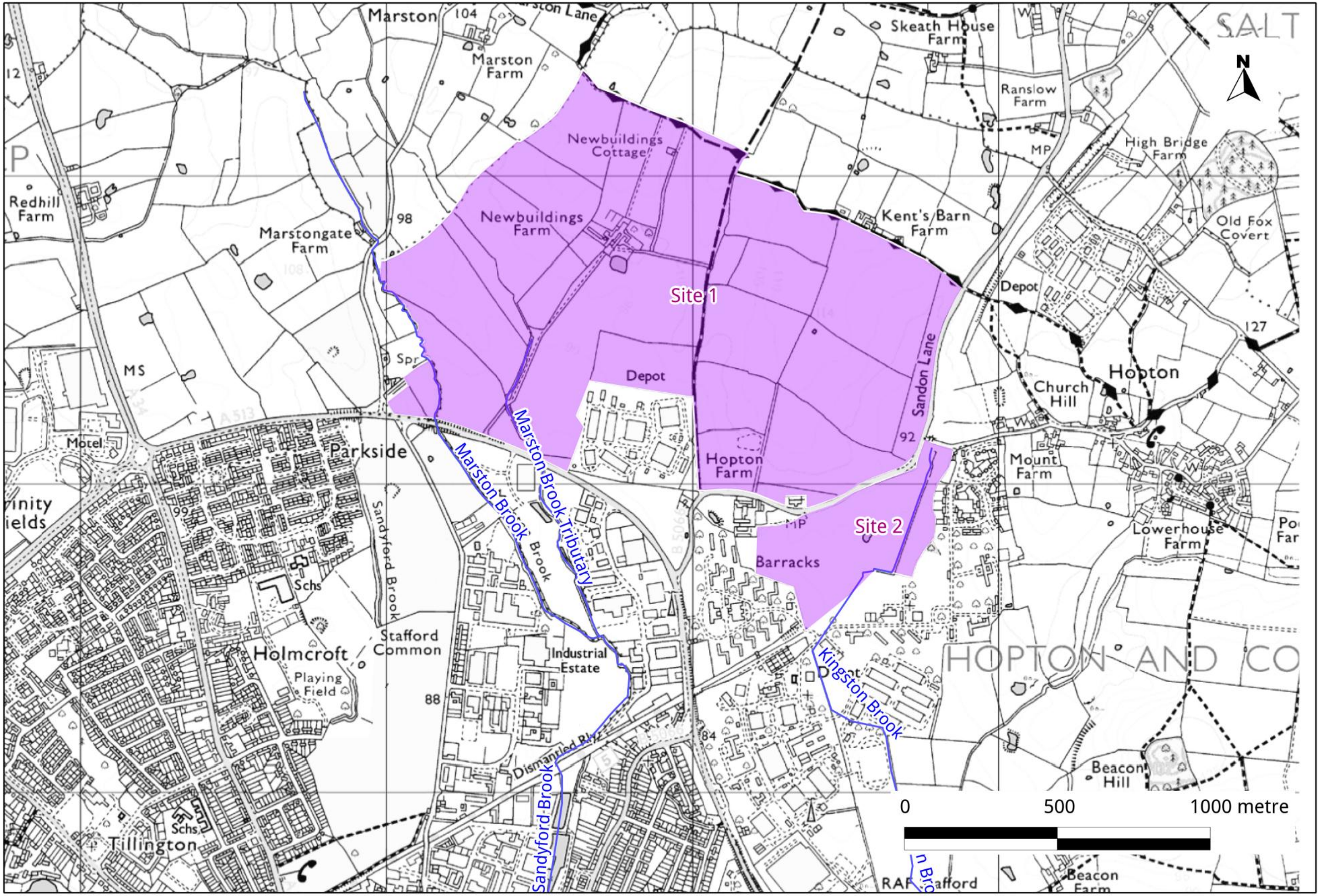

Figure 1: Site location

1.3 Previous studies

EA flood mapping

A request was made to the Environment Agency for their latest flood studies and historical data for Marston Brook and Kingston Brook.

JBA Consulting carried out a flood study in 2007 as a part of Strategic Flood Risk Mapping (SFRM) on behalf of the Environment Agency. Appendix 1 includes the JBA report and modelling data received from the EA.

The study covers approximately 2.5 km of Sandyford Brook from the Isabel Trail (disused railway at BNG coordinate: 392559, 325087) to its confluence with the River Sow.

The hydrological assessment used in the SFRM model is based on the Revitalised Flood Hydrograph (ReFH) model.

In the SFRM study, flows from the hydrology study were routed through an ISIS model for the following return periods: 20 year, 50 year, 75 year, 100 year, 200 year and1000 year.

Using a Digital Terrain Model (DTM) derived from LiDAR, the flood extents were generated based on maximum flood levels.

Strategic Flood Risk Assessment

A level 1 SFRA[1] was carried out by Halcrow in 2007. There was no additional detailed study of Marston Brook or Kingston Brook as a part of the SFRA.

Project BORONA – Flood Risk Assessment

This study covers Kingston Brook immediately downstream of Newbuildings Farm throughout the MOD site. The aim of the study was to assess flood risk within the MOD site. The site had been considered to relocate brigades from Germany to the UK.

According to the Planning Application files on the Staffordshire council website, the purpose of this study was to determine the risk of surface water and fluvial flooding as part of the redevelopment of the MOD site in 2009.

1.4 Data collection and sources

Previous studies

Previous modelling studies were reviewed and examined to gain an understanding of the background, mechanisms and history of flooding within the study area.

LiDAR

Figure 2 shows the area where LiDAR (filtered and unfiltered) data was obtained from the Environment Agency.

The LiDAR data has a lateral resolution of 2 metres and was surveyed in February 2006.

1 http://www.staffordbc.gov.uk/live/Documents/Forward%20Planning/LDF/SFRA-Level-1.pdf

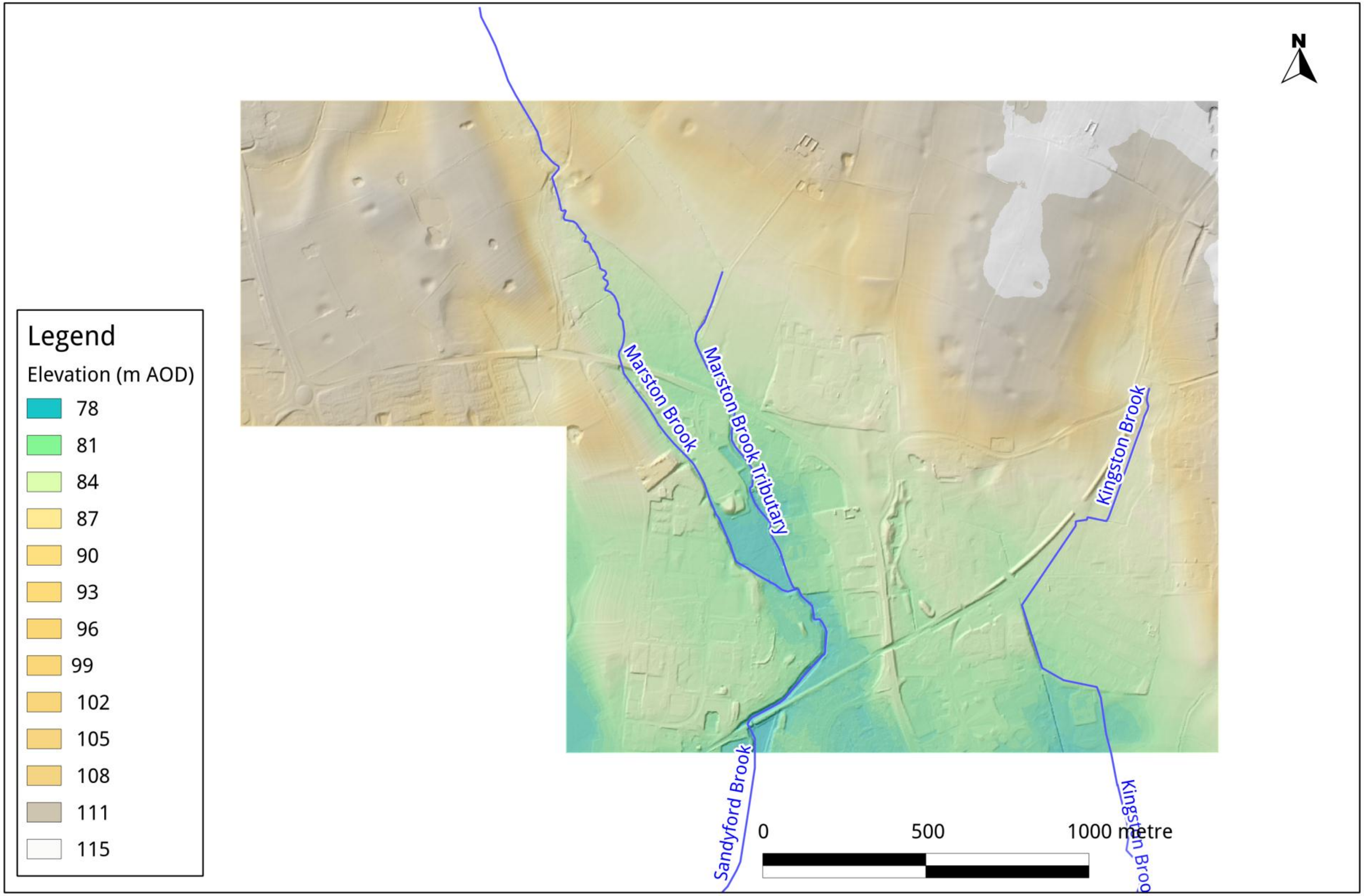

Figure 2: Digital Terrain Model from the LiDAR data

Topographic survey

Lutra Consulting commissioned Total Surveys Limited to perform a topographic survey covering river cross sections and hydraulic structures in May 2012. The survey was carried out in accordance with version 3.0 of the Environment Agency National Standard Contract and Specification For Surveying Services.

Figure 3 shows the location of the surveyed cross sections. Further details of the topographic survey are presented in Appendix 2.

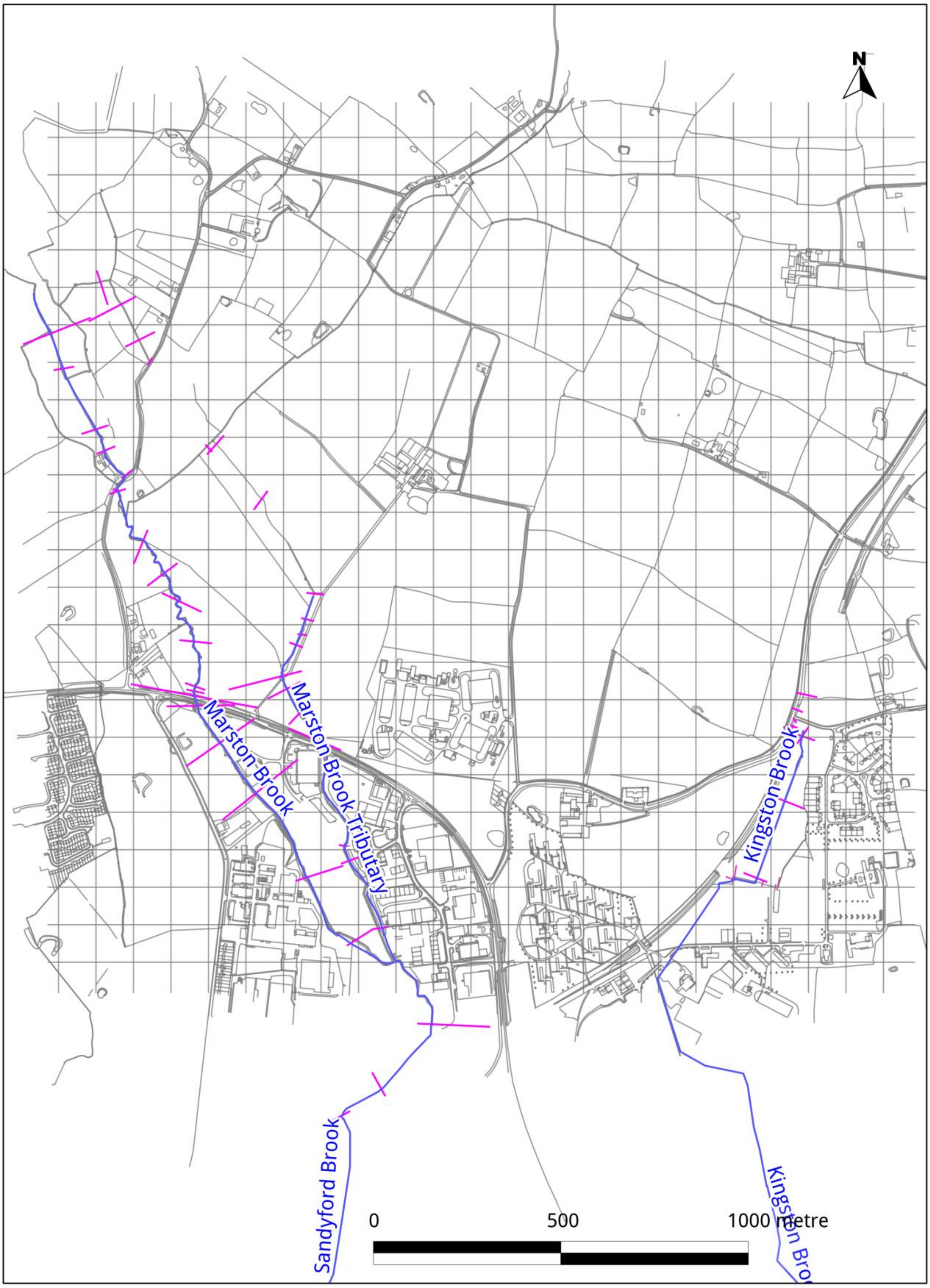

Figure 3: Surveyed cross section locations (May 2012)

2 Hydrology

2.1 Sandyford Brook/Marston Brook

The existing SFRM model for Sandyford Brook contains an inflow at node SAND_2451 which represents the flow contribution from the Marston Brook catchment.

For the purpose of this study, the inflow was split into 3 hydrographs:

- Upstream flow applied to the first node in the Marston Brook
- Upstream flow applied to the first node in the Marston Brook tributary
- Lateral flow distributed from downstream of the A513 to the most downstream node

Each of those 3 inflows was scaled down based on the associated catchment size from the original SFRM model.

Figure 4 below shows the catchments for each of the above inflows.

2.2 Kingston Brook

The lateral inflow at node SAND_2451 from the original Sandyford Brook model does not account for flow coming from the Kingston Brook catchment.

The Kingston Brook and Marston Brook catchments are very similar in terms of land-use, soil type and topographic features. It is anticipated that the rainfall event on both catchments will have similar characteristics due to their close proximity.

Considering the similarities and close proximity of the two catchments, it was deemed appropriate to estimate the inflow hydrograph for the Kingston Brook catchment by scaling the inflow from SAND_2451 based on the differences in catchment areas.

The size of Kingston Brook catchment upstream of the MOD site is 1.72 km2 to the east of Marston Brook whereas the size of the Marston Brook catchment is 6.03 km2. A scaling factor of 0.285 has been used to scale down the Marston Brook inflow hydrograph for use in the Kingston Brook model. Figure 4 highlights the catchment outlines.

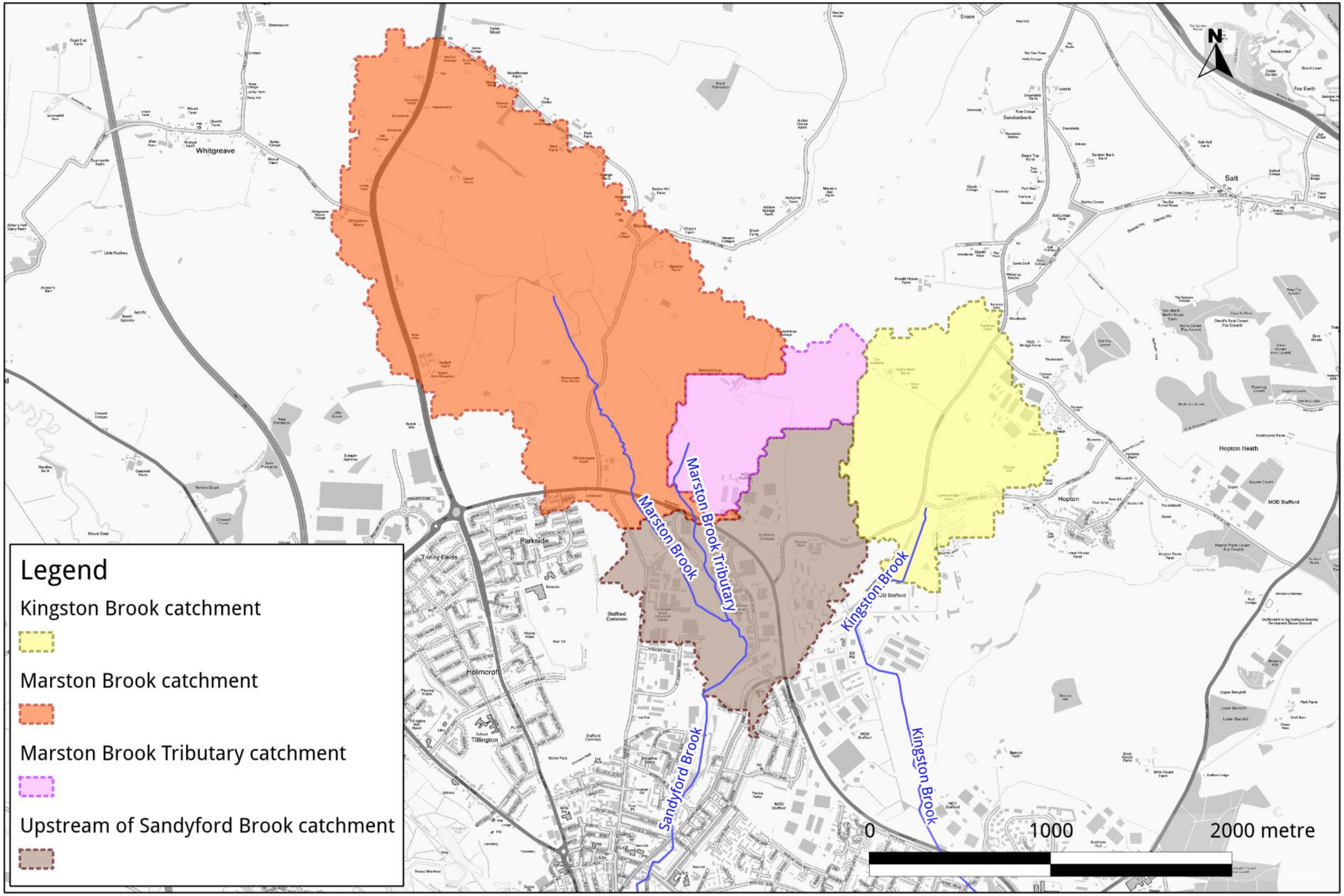

Figure 4: Hydrological catchments

3 Hydraulics

3.1 Sandyford Brook/Marston Brook

Marston Brook flows from north to south as it approaches the site. The channel is generally heavily vegetated with large trees on either side. Several road crossings and farm access bridges intersect the watercourse.

The floodplain mainly consists of farmland for cattle grazing. There are several hedges with dense vegetation across the floodplain. On the right-bank, ground levels rise significantly. There are no major buildings or hydraulic features within this section of the floodplain. During a high flood event, Marston Brook floodplain within Site 1 would form a secondary channel running in parallel to Marston Brook.

South of the site, immediately downstream of the A513 there are industrial buildings within the floodplain and the stream flows through well-defined sections.

Drains from farmlands join Marston Brook on both sides of the watercourse through the study area.

Boundary conditions

An upstream boundary condition for Marston Brook was adopted from the SFRM study as described in the hydrology section. Figures 5 to 7 show the inflow hydrographs applied to Marston Brook, the Marston Brook tributary and the lower region of the Marston Brook catchment.

Downstream boundary conditions were derived from stage result curves from the original SFRM model (Sandyford Brook model) at the crossing located at the Isabel Trail. Figure 8 shows the water level time series for the 100 year and 1000 year events. There were no results in the SFRM model for the 100 year with climate change event. 1000 year downstream boundary conditions were used instead.

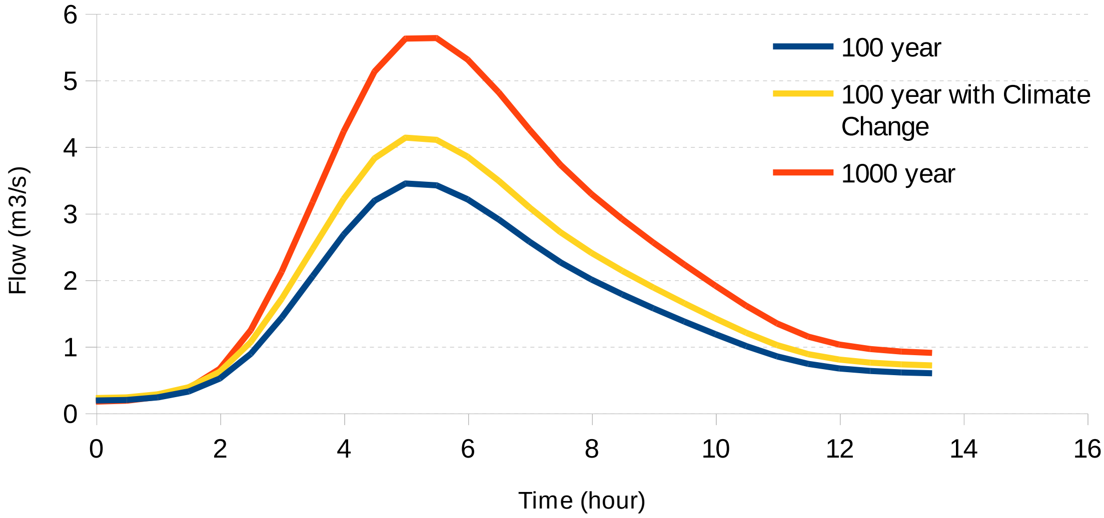

Figure 5: Inflow hydrographs from Marston Brook catchment

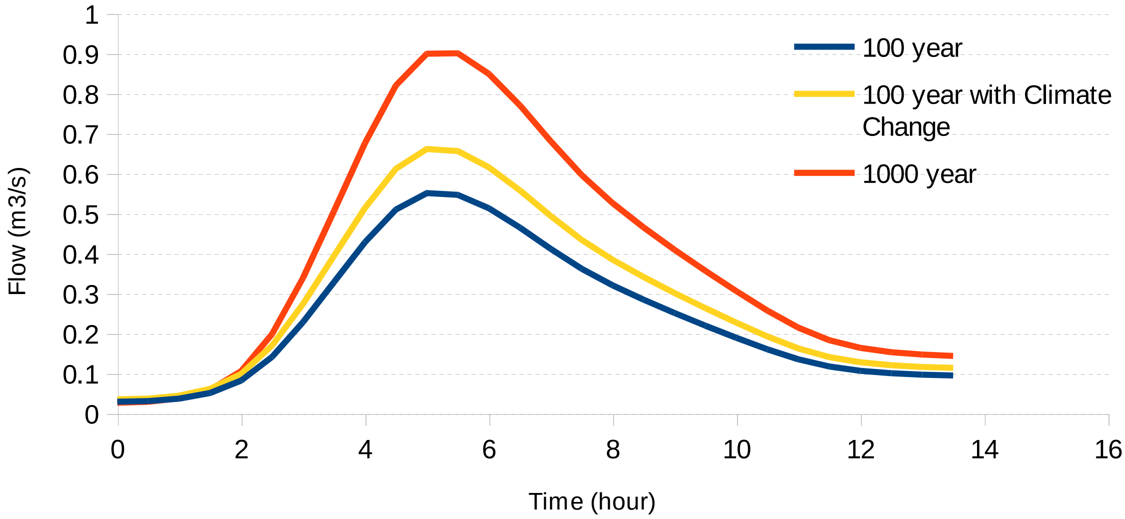

Figure 6: Inflow hydrographs from Marston Brook tributary catchment

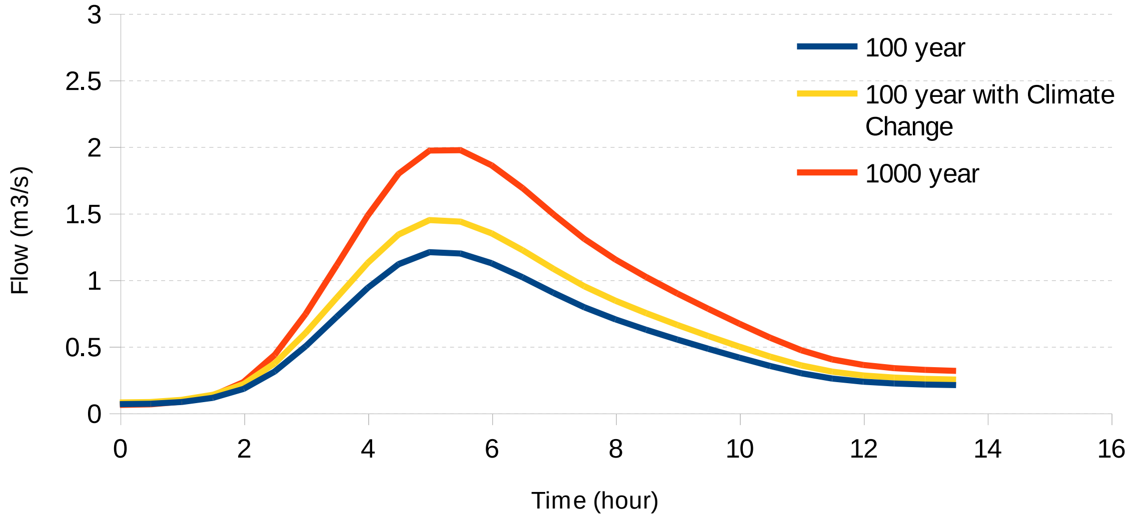

Figure 7: Lateral flow from the lower part of Marston Brook catchment

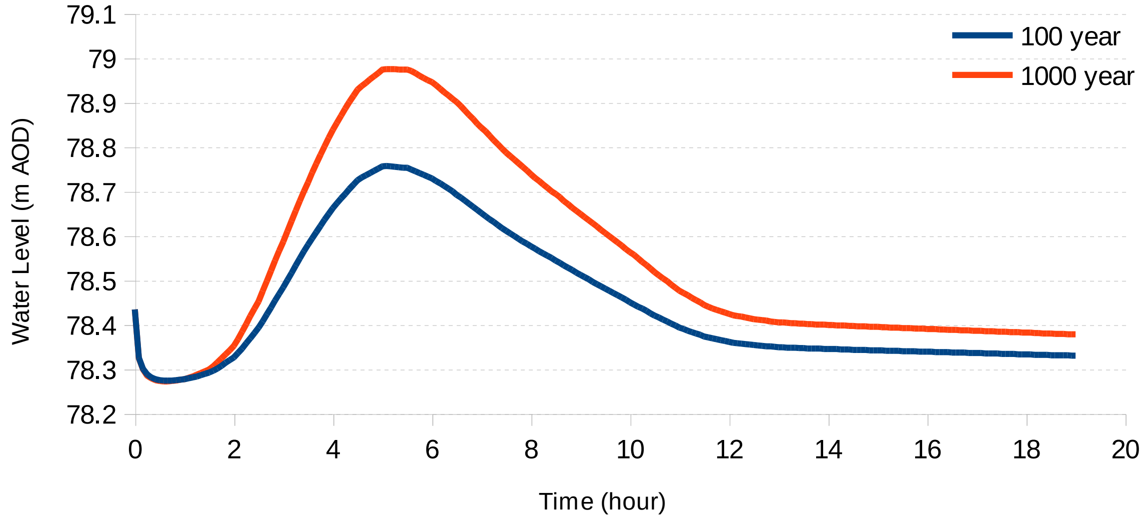

Figure 8: Downstream boundary condition for Marston Brook

Roughness

Hydraulic roughness depends on the vegetation, geomorphology of the channel, degree of meandering, rate of change of cross sectional area and depth of water in the watercourse.

Manning's n roughness values were chosen for the purpose of this study. The values were estimated based on a site visit, aerial photography and use of hydraulic literature[2].

The floodplain is mainly grassland within the study area. The flow direction within the floodplain is generally north to south through uniform channel cross sections. The Marston Brook tributary (to the east of Site 1) is very shallow with dense vegetation growing up to and above the bank level.

Appendix 3 shows photos of the floodplain and main channel taken during a site visit.

Manning's n roughness values of 0.045, 0.065 and were used for Marston Brook, Marston Brook tributary respectively. Manning n roughness values within the floodplain varied based on the land-use. Figure 10 shows different roughness values used in TUFLOW.

Structures

The main hydraulic structures within the study area are culverts and farm access bridges. Backwater caused by the constriction of flow through structures affects the flooding mechanism of the site.

Marston Brook flows through several farm access bridges north of Marston Lane, before it enters a 46 metre long circular culvert beneath Marston Lane. The Marston Lane culvert bends almost 90 degrees to the west. The stream then flows north to south just downstream of Marston Lane where there are signs of scouring and deposition around the culvert outlet. In an extreme event, flood water would bypass the culvert under Marston Lane by flowing over Marston Lane itself towards the culvert outlet.

The stream continues to flow in a southerly direction to the west of the site where there are no major hydraulic structures. Towards the south west edge of Site 1, the stream flows under the A513 (Beaconside). The culvert is a circular conduit, 1.1 m in diameter and approximately 27 metres long. The inlet of the culvert is heavily obscured by debris and tree branches.

Marston Brook flows southerly after the A513 (Beaconside) and eventually becomes Sandyford Brook before it flows under the disused railway embankment (just upstream of Astonfields Balancing Lakes) where the downstream boundary condition is located.

Within Site 1, there is a small farm drainage ditch, some 200 metres east of Marston Brook running parallel to the main watercourse. The drainage ditch flows under the A513 (Beaconside) through a corrugated metal culvert and joins Marston Brook approximately 620 metres downstream of the A513.

During a major flood event, water is expected to flow from Marston Brook towards the drainage ditch to the east before leaving the site through the eastern culvert under the A513. Any water spilling over the A513 would run towards the industrial buildings located in the floodplain to the south of the A513.

Model schematisation

A 1D-2D approach was adopted for the purpose of this study. Flow and water levels within the channel were calculated in ISIS (a 1D hydrodynamic model). The information from ISIS passed throughout the simulation to TUFLOW (a 2D hydrodynamic model).

- The 2D domain extent is confined between Marston Brook and Marston Brook

2

OPEN-CHANNEL HYDRAULICS, VEN TE CHOW

Tributary as shown in Figure 9. The western edge of the domain extends throughout Marston Lane (~ 93.0 mAOD) and Common Road; the eastern edge of the domain follows the high ground approximately parallel to Marston Brook Tributary. The domain extends to the disused railway.

- The dimension of cell size of 2D domains should be sufficiently small to represent the hydraulic behaviour of the floodplain. A 2 metre cell size was chosen for the TUFLOW part of this model.
- Different roughness values were applied to the 2D domain based on the aerial photography.. Most of the floodplain within Site 1 is farmland divided by dense hedges. South of the A513, there are several office blocks and access roads within the floodplain. Following Manning's n roughness values were applied to each land-use within the 2D domain:
    1. building and office blocks: 0.50
    2. heavy woodland: 0.10
    3. the road tracks and paths: 0.02

During high-order event water will flow from Marston Brook and following the slope of the ground flow towards downstream where Marston Brook Tributary crosses the A513. Flood depth within the area bounded by A513, Marston Brook and Marston Brook tributary is relatively high as the water backs up behind the A513. The A513 functions as a critical hydraulic feature during large flood events. The road is generally high above Marston Brook (~ 88.50 m AOD) but drops to below 83.0 m AOD where it intersects with the Marston Brook tributary. In a high-order event flood water will spill over parts of the A513 and flow into the industrial estate around Paton Drive as shown in figure 12.

3.2 Kingston Brook

Kingston Brook first runs southwards then westwards through Site 2 before entering a culvert under the MOD site. The exact alignment and condition of the culvert is unknown throughout the MOD site due to the restricted access to their site when the topographic survey was carried out.

The brook becomes an open channel to the west of the MOD site and flows in parallel to Marston Brook and eventually joins the River Sow.

The stream is dry under normal conditions and is fed by several farm drains during rainfall events.

To the west of the stream on Site 2 is a disused railway embankment. The floodplain to the east is relatively flat but rises significantly adjacent to the properties along Spode Avenue.

Boundary conditions

Inflow hydrographs for Kingston Brook were derived as described in hydrology section. The inflow hydrographs were applied to the most upstream point of the stream within Site 2.

The exact arrangement of culverts draining into the north of Kingston Brook on Site 2 was not clear during the site visit. The hydrograph for Kingston Brook has therefore been applied to the most upstream section within Site 2 leading to a conservative estimate of flood levels within the site.

A normal depth boundary was applied to the downstream end of the model just downstream of the outlet of the long culvert passing under the MOD site.

Results of sensitivity testing showed the downstream boundary condition not to affect the maximum water level within Site 2.

Roughness

Kingston Brook is shallow and narrow and contains dense vegetation. A Manning's n roughness coefficient of 0.065 has been applied to the channel. Surrounding floodplains are used for cattle grazing and feature long grass where a coefficient of 0.05 has been applied.

Structures

Kingston Brook flows in an open channel through most of its length within Site 2. There are two circular culverts towards the southern part of Site 2, the first of which is a short culvert under a farm access route. The second culvert is long (~500m), starting at the most downstream end of Site 2 and extending under the adjacent MOD site.

Model schematisation

Similarly to the Marston Brook model, ISIS was chosen to model flows through Kingston Brook. Floodplains on both banks on the northern portion of Site 2 are wide and modelled as extended sections in ISIS. The floodplain becomes flat towards the southern part of Site 2 where ISIS reservoir units have been used to represent the floodplain.

During large flood events, a portion of the flood water will spill over the southern bank of Kingston Brook (where it runs parallel against the boundary of the MOD site) and will flow onto the MOD site. The LiDAR shows the land within the MOD site to be steep and falling in a south-westerly direction. Water will then flow overland to the west of the MOD site where Kingston Brook returns to an open channel. A spill unit with a low discharge coefficient (0.3) was used in the ISIS model to simulate flood water flowing overland and bypassing the 500m long culvert through the MOD site.

Flow passing through (and bypassing overland) the culvert under the MOD site will return to the Kingston Brook to the west of the MOD site continue to flow in a southerly direction. LiDAR data shows bed levels to drop from 86 m AOD (upstream of the culvert) to 81 m AOD at the culvert outlet to the west of the MOD site. This significant drop in elevation means the hydraulic conditions downstream of the long culvert are unlikely to affect those within Site 2.

4 Results

4.1 Sensitivity analysis

As a part of standard modelling practice, validation of the results obtained from modelling software packages is required. Usually validation will be carried out using real world gauged data, anecdotal evidence and historical flood events. Due to the lack of such data at this time a sensitivity analysis was instead carried out on various hydraulic coefficients/parameters to establish the robustness of the model.

According to the Environment Agency's modelling guidance the following sensitivity tests should be carried out for the 100 year event:

- ±10% change in roughness coefficients
- ±10% change in structure coefficients
- ±20% change in upstream and downstream boundary conditions

The results from sensitivity analyses should be comparable with the baseline scenario. Water depths within the study area should not vary by more than 20% or 20 cm when changing the variables above.

Sensitivity tests show the maximum changes in depth within Site 1 and Site 2 are within the EA's acceptable range. The model is therefore deemed to be robust and to produce meaningful results. A full set of sensitivity results is presented in Appendix 5.

4.2 Results

Maximum water levels and flows were extracted from ISIS model results for the 100 year, 100 year with climate change and 1000 year flood events. Spreadsheets (Kingston_results.xls and Marston_results.xls) in Appendix 6 show the maximum flows and water levels for model cross sections.

ESRI ASCII grid files for maximum water level and maximum flood depth is presented in Appendix 6.

Animation showing the propagation of flooding within Site 1 is also included in Appendix 6.

4.3 Mapping

Maximum water levels were used to generate flood maps within Site 2. The GRASS GIS software package was used to generate a raster layer of peak depths (which in turn can be used to generate flood extents). The steps used to generate the maximum depth raster layer are described below:

- Maximum water levels are assigned to cross sections/floodplain sections within associated GIS layers.

- Within GRASS GIS, the cross section GIS layer is loaded as a layer with linear geometry. In order to interpolate water levels between sections, the linear layer was converted to a point geometry layer with points at 2 metre intervals along cross sections.
- The resultant point layer was converted to a raster layer using its maximum water level attribute.
- GRASS was used to generate a Triangulated Irregular Network (TIN) from raster points.
- Reservoir polygon layers were then converted to a raster layer using the maximum water level attribute.
- The reservoir raster layer was stamped onto the cross section TIN to form a complete surface of peak flood water levels.
- In order to determine the peak flood depth, ground levels from the DTM were deducted from the result from the previous step (maximum water level surface). Negative values (representing dry areas) were discarded.
- The result from the previous operation was then converted to a vector layer.
- Flood extent vector layers were then edited manually to remove small dry islands and hydraulically unconnected wet areas.

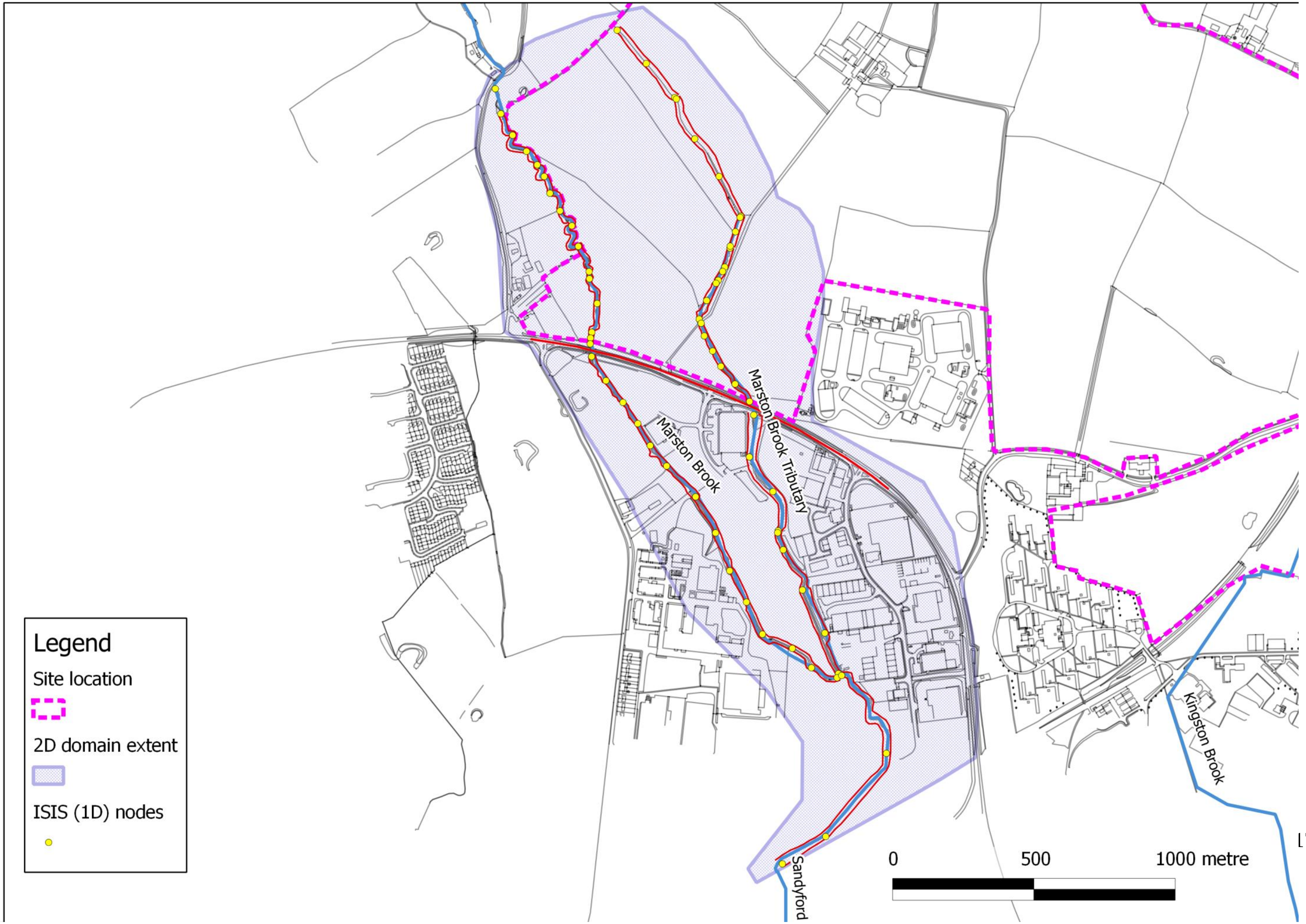

Figure 9: 2D domain extend

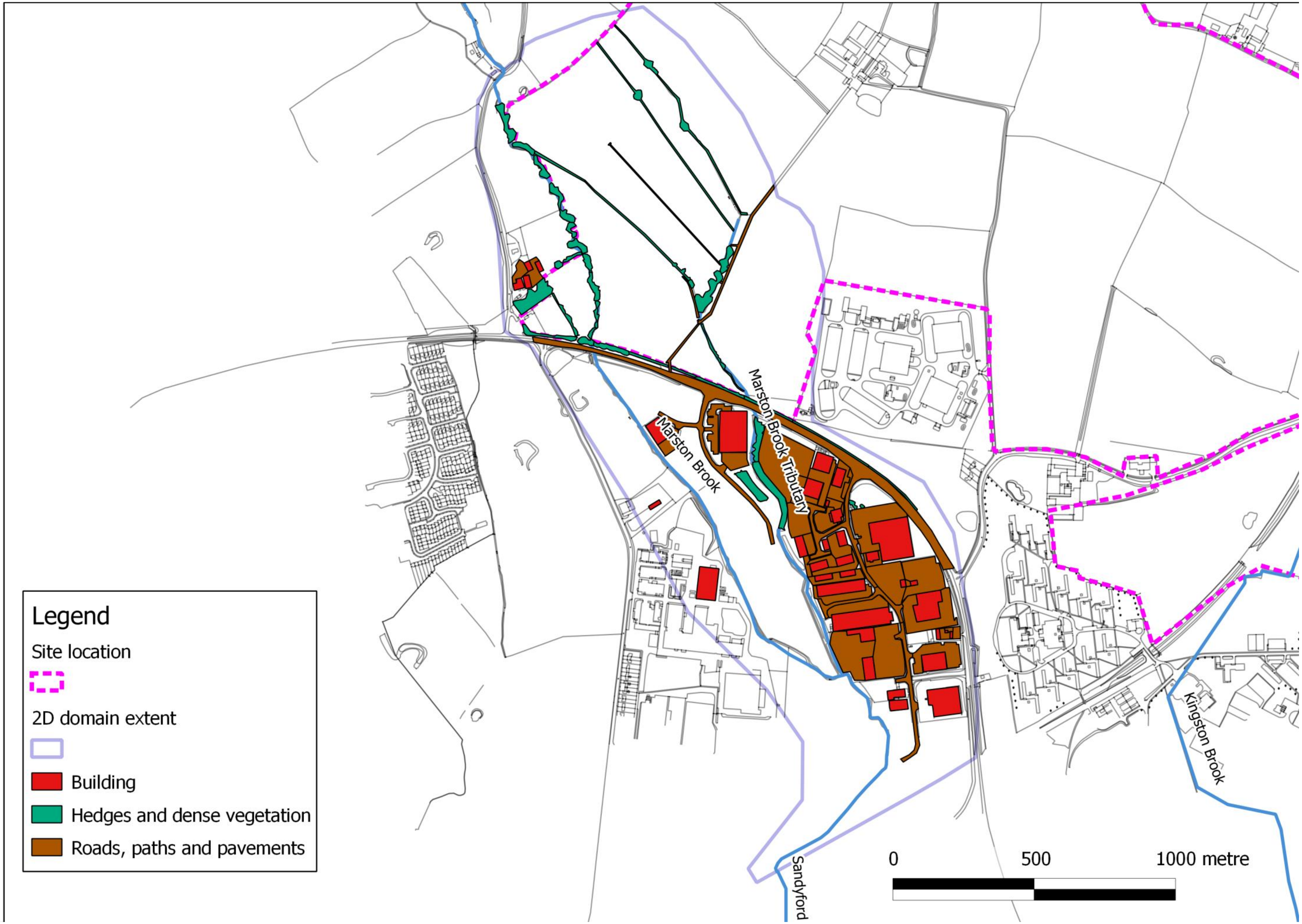

Figure 10: Different hydraulic roughness

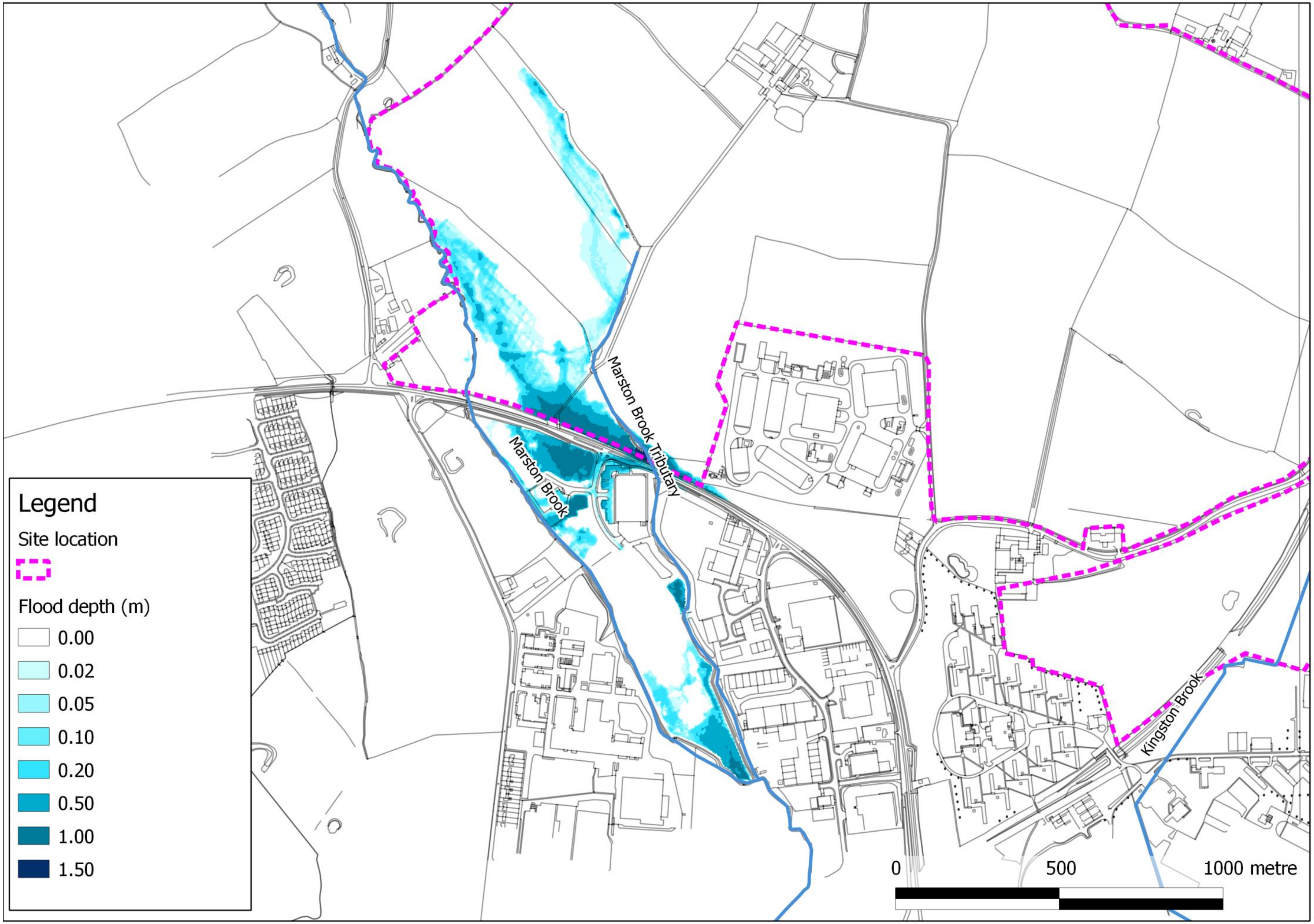

Figure 11: Flood depth map for 100 year with climate change